Fukushima: Status for en igangværende ulykke

Nonbøl, Erik; Hoe, Steen

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Fukushima

status for en igangværende ulykke

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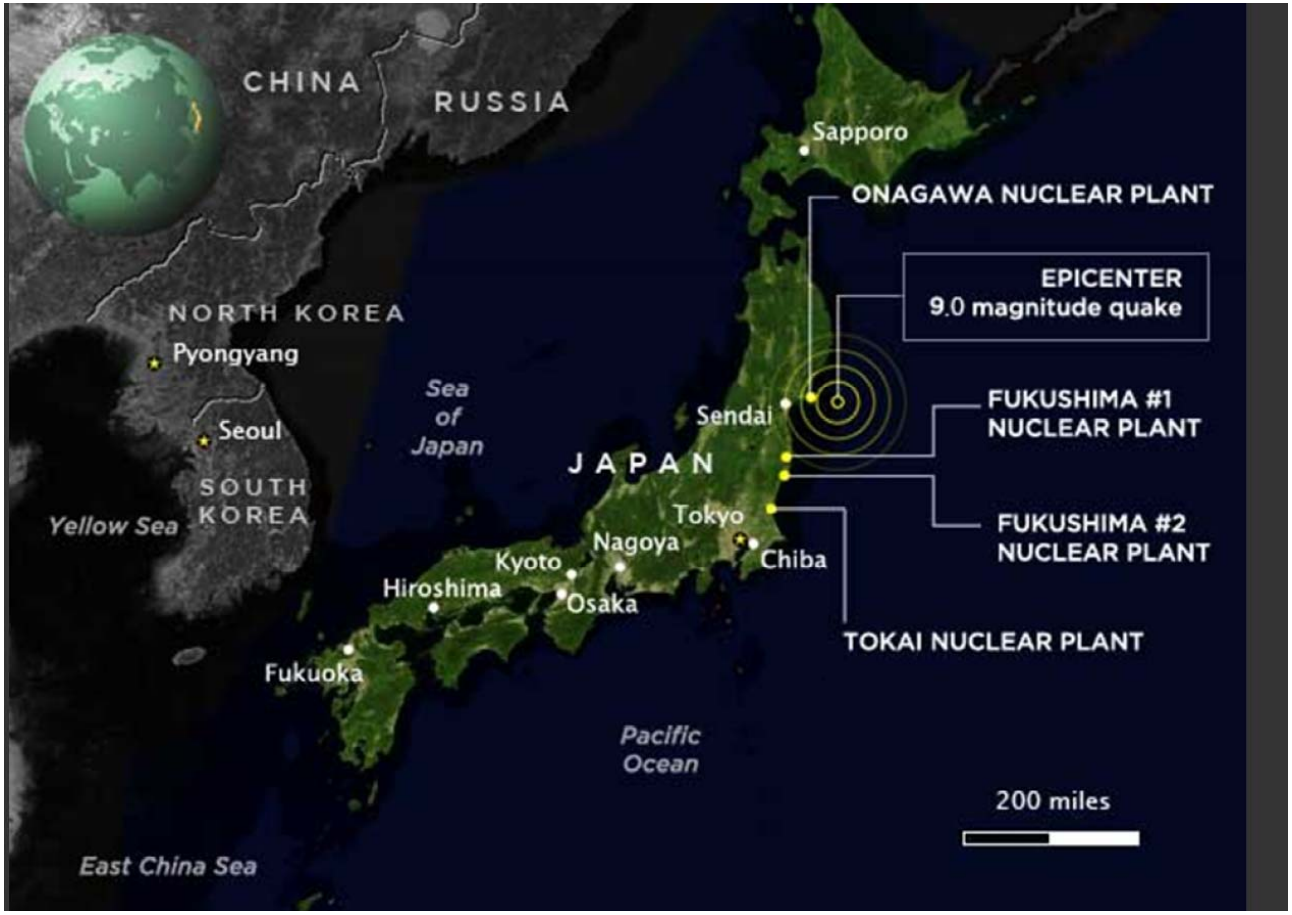
Erik Nonbøl, Risø DTU

Steen Hoe, Beredskabsstyrelsen

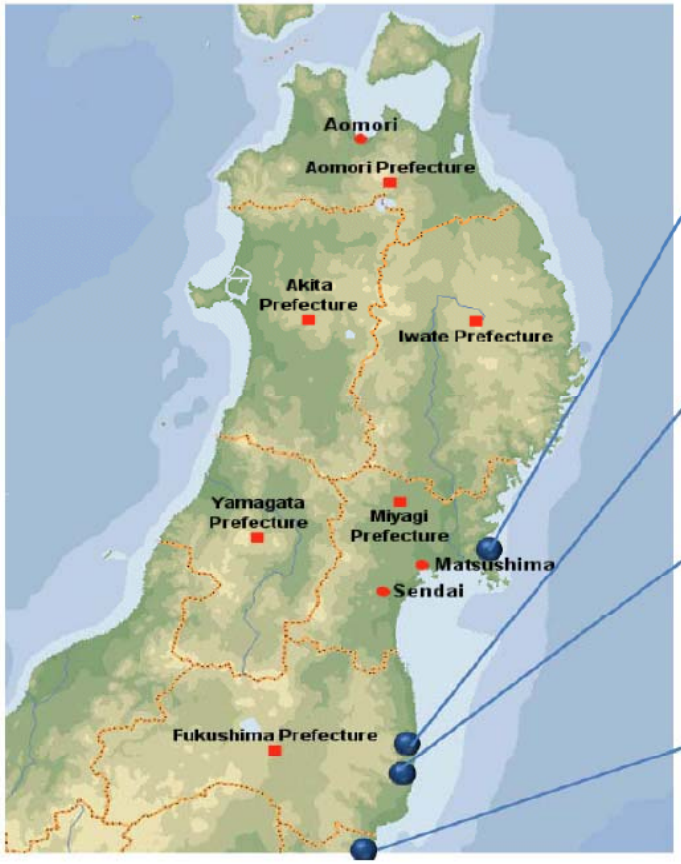
Presentation based on

- Dr Minoru Saito (JNES)
- TEPCO
- IAEA
- DOE
- NISA


CHINA
RUSSIA
Sapporo
ONAGAWA NUCLEAR PLANT
EPICENTER
9.0 magnitude quake
NORTH KOREA
Pyongyang
Sea
of
Japan
Sendai
FUKUSHIMA #1
NUCLEAR PLANT
Seoul
JAPAN
SOUTH
KOREA
Yellow Sea
Tokyo
FUKUSHIMA #2
NUCLEAR PLANT
Nagoya
Chiba
Kyoto
Hiroshima
Osaka
TOKAI NUCLEAR PLANT
Fukuoka
Pacific
Ocean
200 miles
East China Sea

1-3. Nuclear reactors near epicenter of the earthquake

Location of the Nuclear Installations



Onagawa
- Unit1: 524 MW, 1984-
- Unit2: 825 MW, 1995-
- Unit3: 825 MW, 2002-

Fukushima Ⅰ
- Unit1: 460 MW, 1971-
- Unit2: 784 MW, 1974-
- Unit3: 784 MW, 1976-
- Unit4: 784 MW, 1978-
- Unit5: 784 MW, 1978-
- Unit6: 1,100 MW, 1979-

Fukushima Ⅱ
- Unit1: 1,100 MW, 1982-
- Unit2: 1,100 MW, 1984-
- Unit3: 1,100 MW, 1985-
- Unit4: 1,100 MW, 1987-

Tokai Ⅱ (1,100 MW, 1978-)

2-1. Summary of Fukushima Dai-ichi NPS

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
	BWR-3	BWR-4	BWR-4	BWR-4	BWR-4	BWR-5
PCV Model	Mark-1	Mark-1	Mark-1	Mark-1	Mark-1	Mark-2
Electric Output (MWe)	460	784	784	784	784	1100
Max. pressure of RPV	8.24MPa	8.24MPa	8.24MPa	8.24MPa	8.62MPa	8.62MPa
Max. Temp of the RPV	300℃	300℃	300℃	300℃	302℃	302℃
Max. Pressure of the CV	0.43MPa	0.38MPa	0.38MPa	0.38MPa	0.38MPa	0.28MPa
Max. Temp of the CV	140℃	140℃	140℃	140℃	138℃	171℃(D/W) 105℃(S/C)
Commercial Operation	1971,3	1974,7	1976,3	1978,10	1978,4	1979,10
Emergency DG	2	2	2	2	2	3*
Electric Grid	275kV × 4				500kV × 2	
Plant Status on Mar. 11	In Operation	In Operation	In Operation	Refueling Outage	Refueling Outage	Refueling Outage

* One Emergency DG is Air-Cooled

Wave

Automatic shut-down of nuclear reactors

●11 reactors were automatically shut-down

- Onagawa Units 1,2,3
- Fukushima Dai-ichi (I) Units 1,2,3
- Fukushima-Dai-ni (II) Units 1,2,3,4
- Tokai Dai-ni (II)

●3 reactors were under periodic inspection

- Fukushima Dai-ichi (I) Units 4,5,6

-After the automatic shut-down of, Units 1-3 at Onagawa SITE, Unit 3 at Fukushima II Site, and the Unit at Tokai II Nuclear Power Station the NPP was put in cold shut down safely.

-As for the Units 1,2,4 at Fukushima *Dai-ni* (II)Site, the operator of the station reported NISA nuclear emergency situation because the temperature of the suppression pools became more than 100 ℃, but afterward the three units have been cold shut down.

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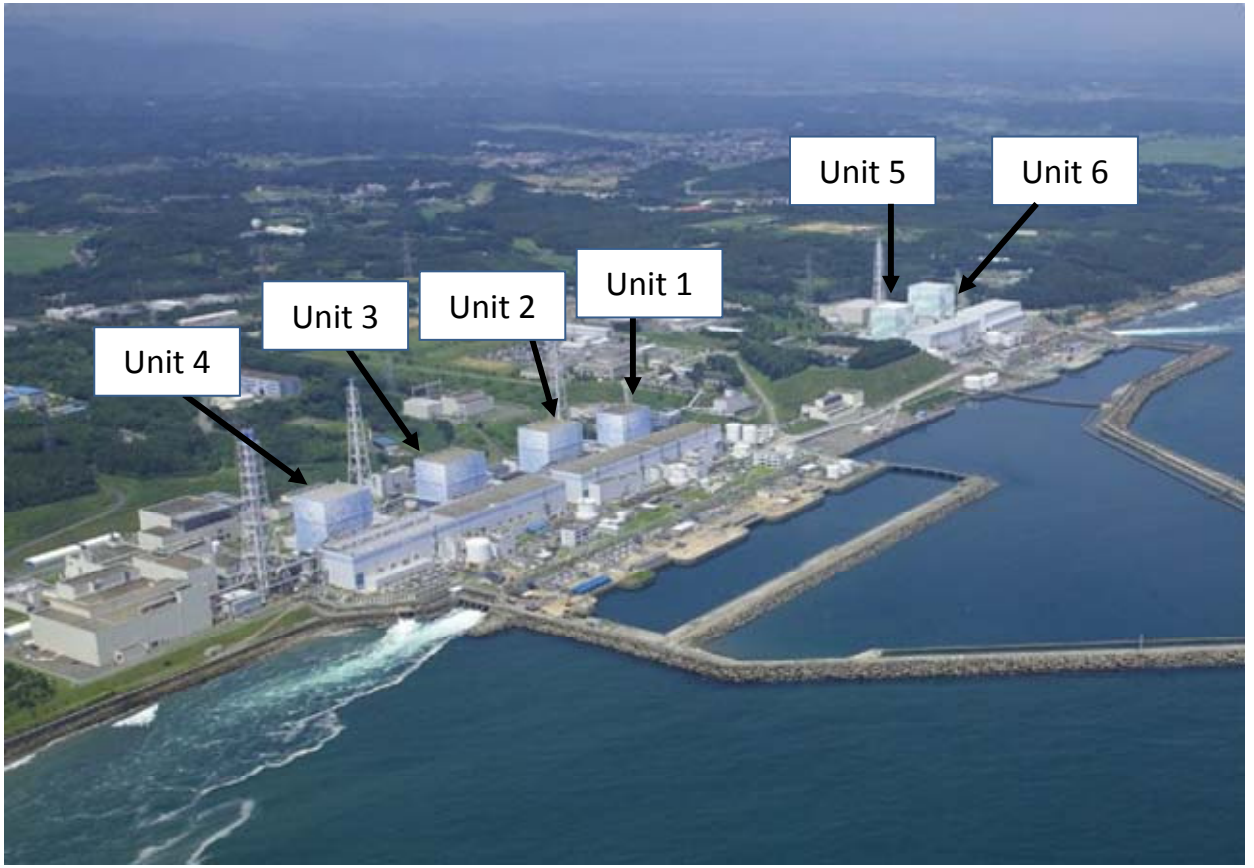
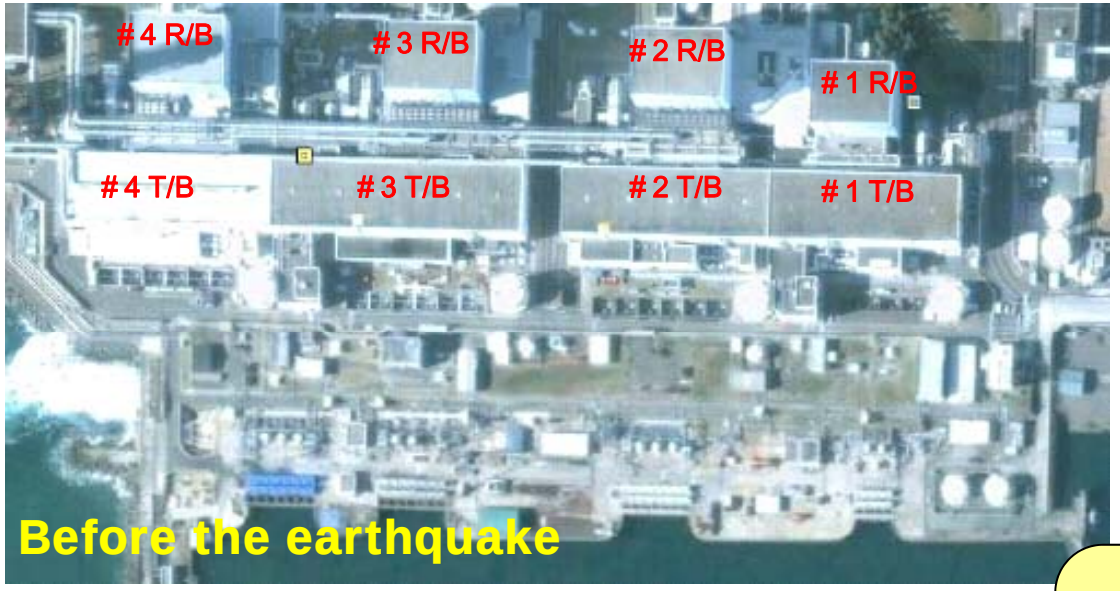
Layout of Fukushima Dai-ichi Nuclear Plant Site



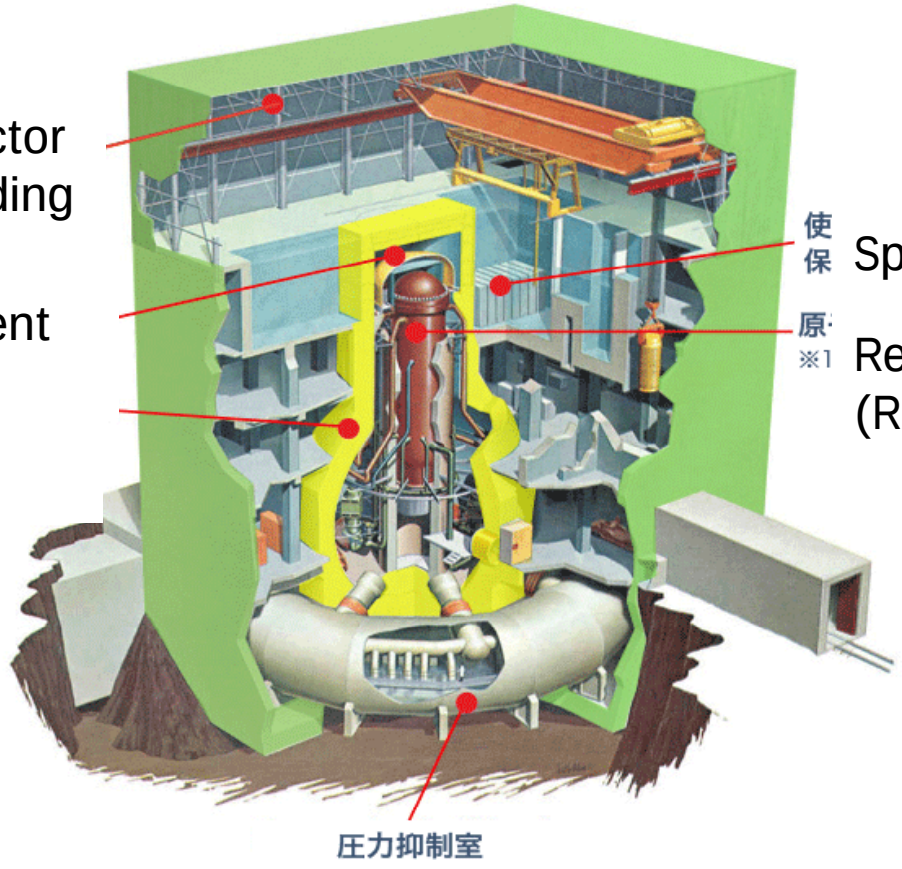
Fukushima 1 (Dai-ichi) NPP



Many structures facing the bay are destroyed

Source: Google Earth

Overview of Mark-1 Type BWR (Units 1,2,3 and 4)



出典：ht s/BWR_illustration.jpg

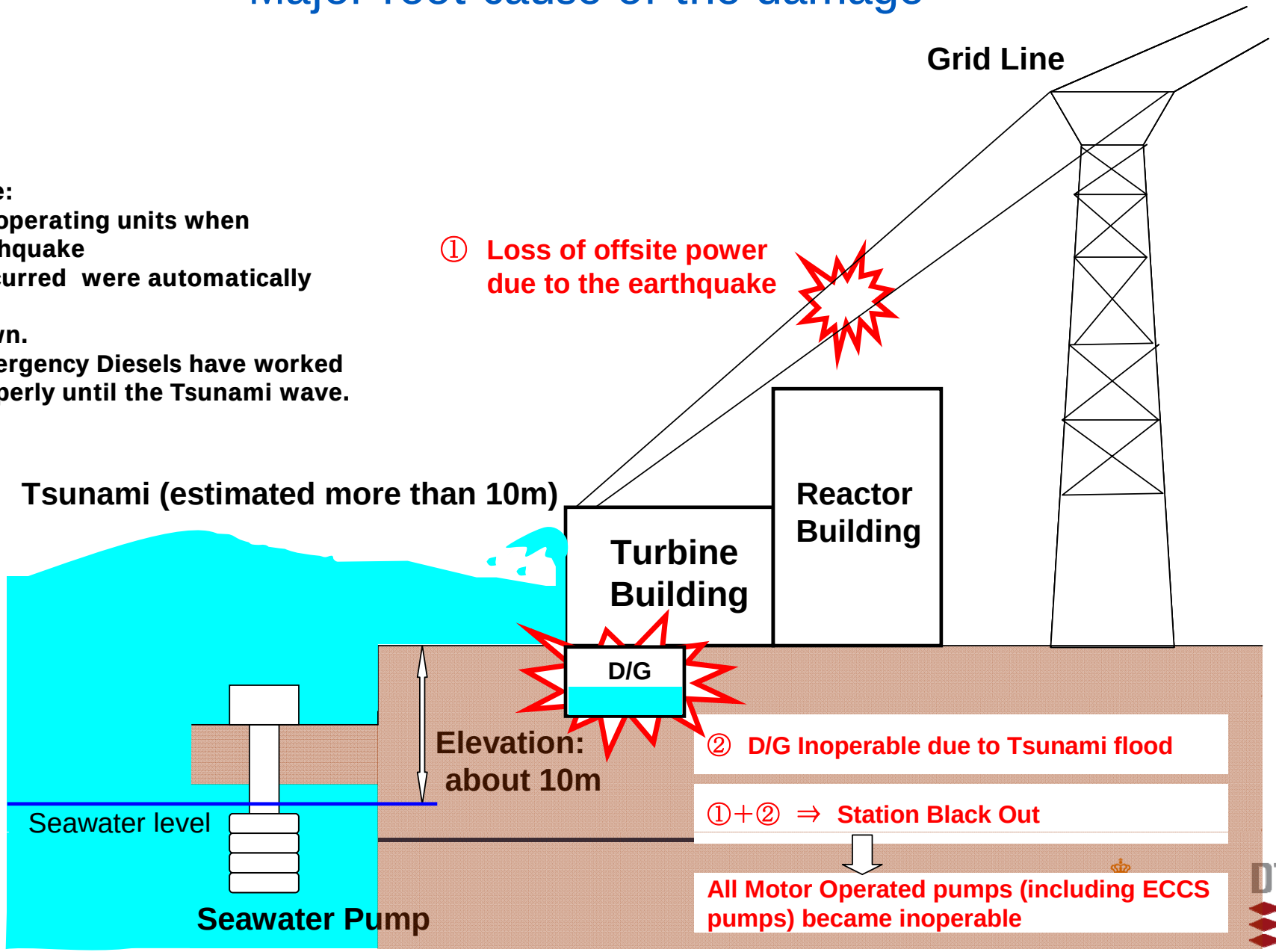
Unit	1	2	3	4	5	6
Number of Fuel Assembly in the Core	400	548	548	-	548	764
Number of Spent Fuel Assembly in the Spent Fuel Pool	292	587	514	1,331	946	876
Number of New Fuel Assembly in the Spent Fuel Pool	100	28	52	204	48	64
Water Volume (m^3)	1,020	1,425	1,425	1,425	1,425	1,497

Condition of the fuel in the Spent Fuel Pool

Unit 1	Unit 2	Unit 3	Unit 4
-Most recent shut down was on Sep.27,2010	- Most recent shut down was on Nov.18,2010	- Most recent shut down was on Sep.23,2010	-Most recent shut down was on Nov.29,2010 -All fuel assembly was removed from the core and located in the pool due to the core shroud replacement

Major root cause of the damage

Note:
-All operating units when earthquake occurred were automatically shut down.
-Emergency Diesels have worked properly until the Tsunami wave.



Beredskabet aktiveres 12 marts

- Beredskabsstyrelsen i operationsberedskab fra fredag - netværkskontakter (fredag aften)
- Nukleart beredskabet etableres lørdag morgen i Birkerød efter første Brinteksplosion.
- Informationsberedskab.
  - Stabsberedskab 15marts
  - Operationsberedskab 16 marts
- Spørge svar central.

Deltagere i det Danske Beredskab

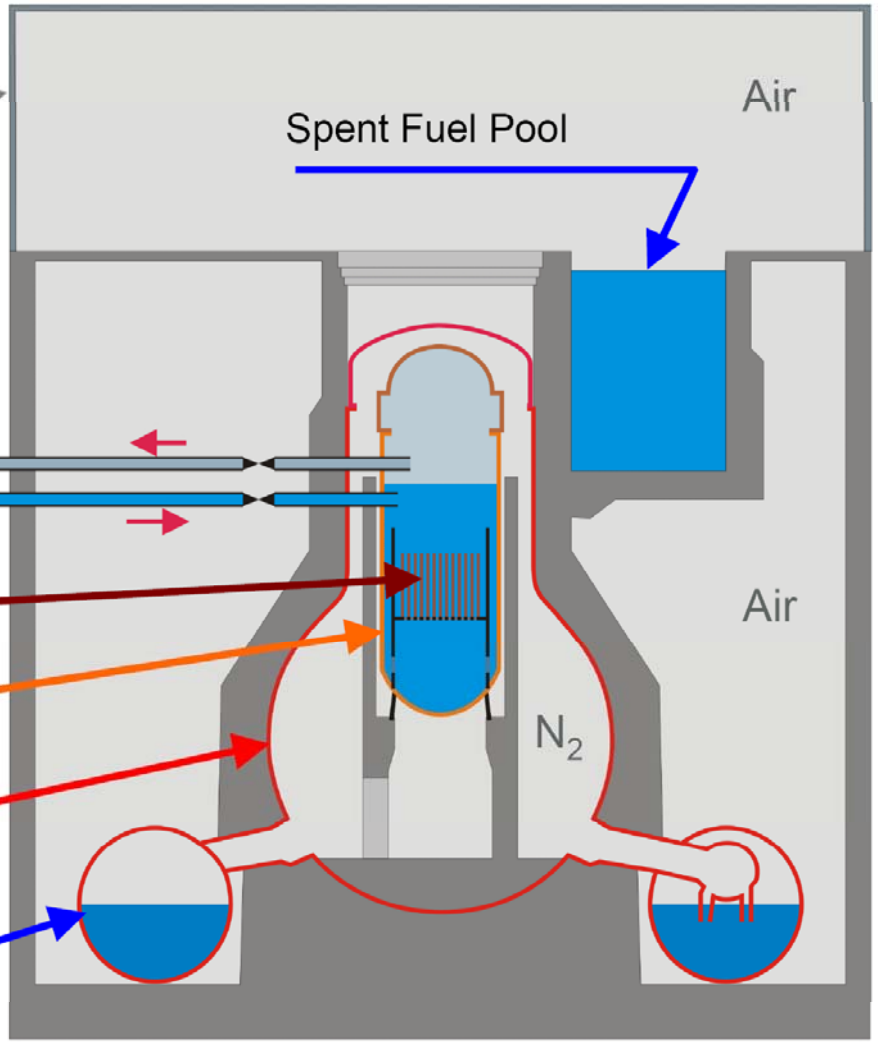
- Nukleart Beredskab 24/7 og
- Statens Insitut for Strålebeskyttelse 24/7
- Risø DTU og DD dagligt
- Fødevareberedskabet
- DMI
- Andre

Danish Nuclear Emergency in “Japan Mode”

- ARGOS 9.0 moved from test to operation – this version could use NWP data from NOMAD *(NOAA Operational Model Archive and Distribution System)*
- Risoe 13/3: Terrain data for Japan (100m horizontal)
- New version of ARGOS for handling 21 horizontal NWP layers within one week.
- ECMWF high resolution data (approx 12km) within 8 days

Reactor design - Fukushima

- Reactor Service Floor (Steel Construction)
- Concrete Reactor Building (secondary Containment)
- Reactor Core
- Reactor Pressure Vessel
- Containment (Dry well)
- Containment (Wet Well) / Condensation Chamber



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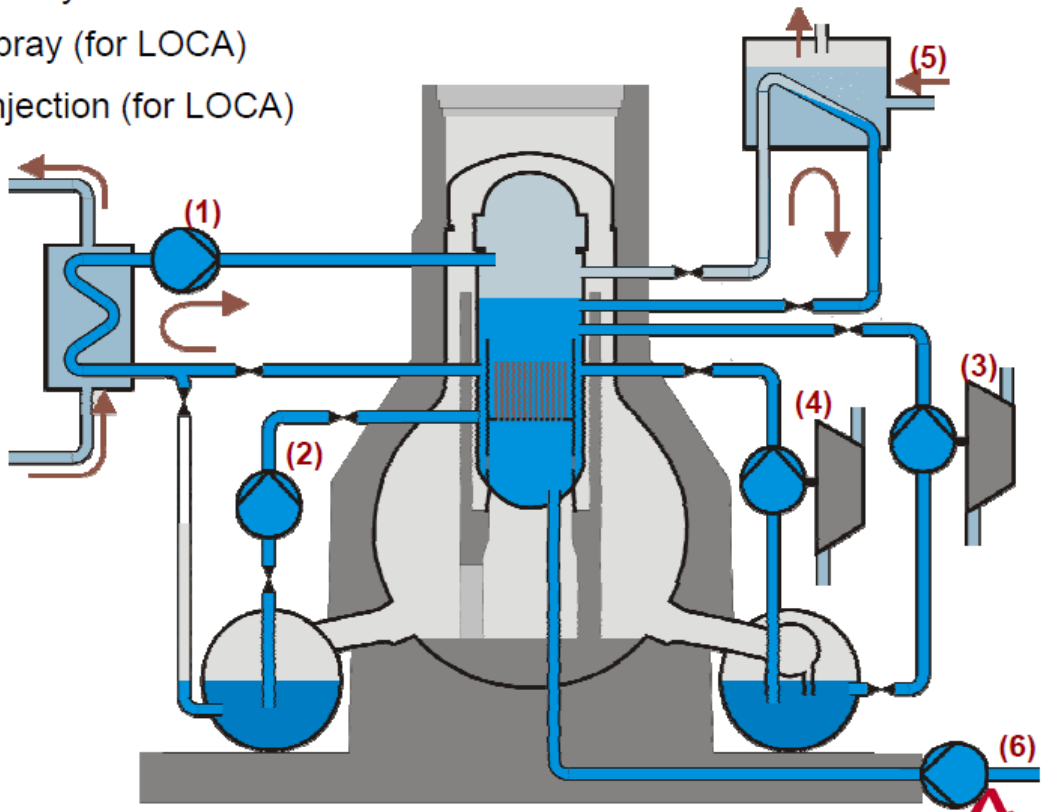
Service Floor

1. Plant Design

- Emergency Core Cooling Systems

1) Residual Heat Removal System
2) Low-Pressure Core Spray (for LOCA)
3) High-Pressure Core Injection (for LOCA)
4) Reactor Core isolation cooling (Unit 2,3 [BWR4])
5) Isolation Condenser (Unit 1 [BWR3])
6) Borating System



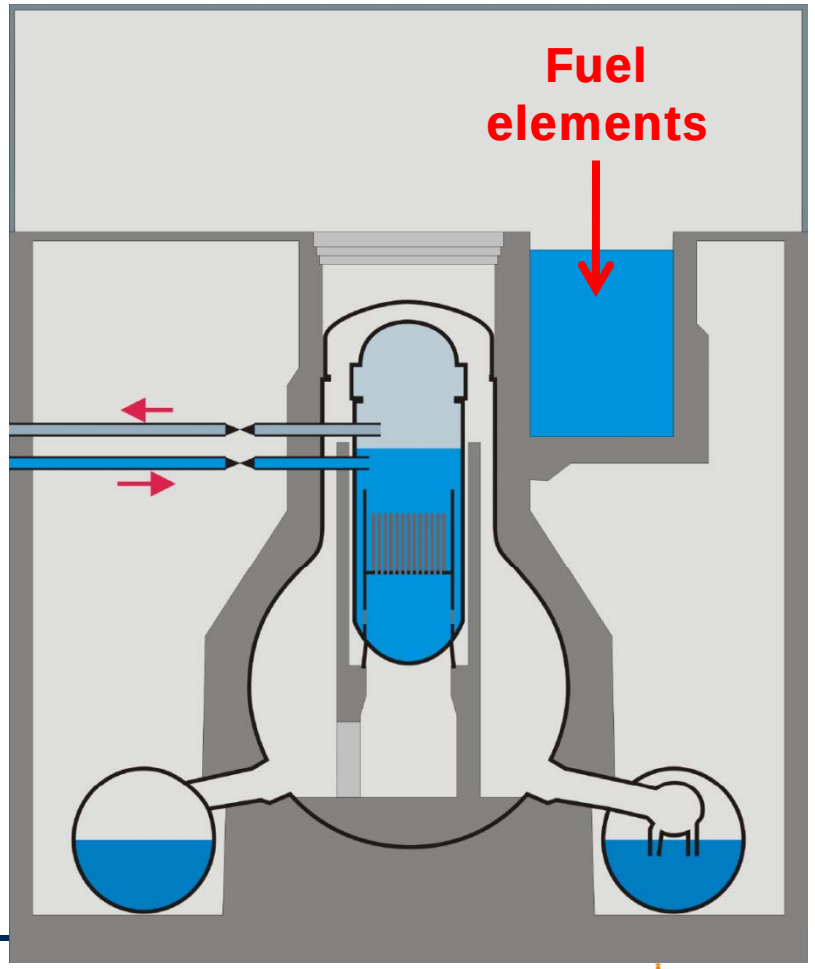
AREVA

Accident progression

11.3.2011

Units 1, 2 and 3 in operation
Units 4, 5 and 6 closed down

Spent fuel pools in top of reactor buildings



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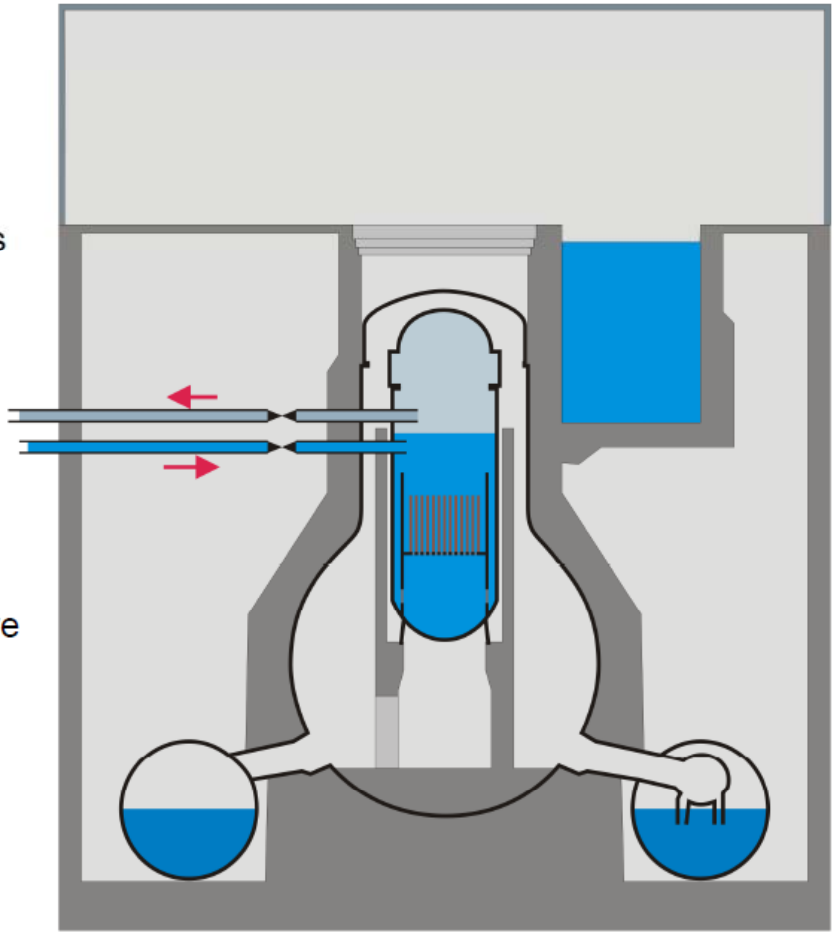
2. Accident Progression

- 11.3.2011 14:46 - Earthquake
  - Magnitude 9
  - Power grid in northern Japan fails
  - Reactors itself are mainly undamaged
- Automatic SCRAM
  - Power generation due to fission stopped
  - Heat generation due to radioactive decay of fission products
    - After SCRAM ~6%
    - After 1 Day ~1%
    - After 5 Days ~0.5%



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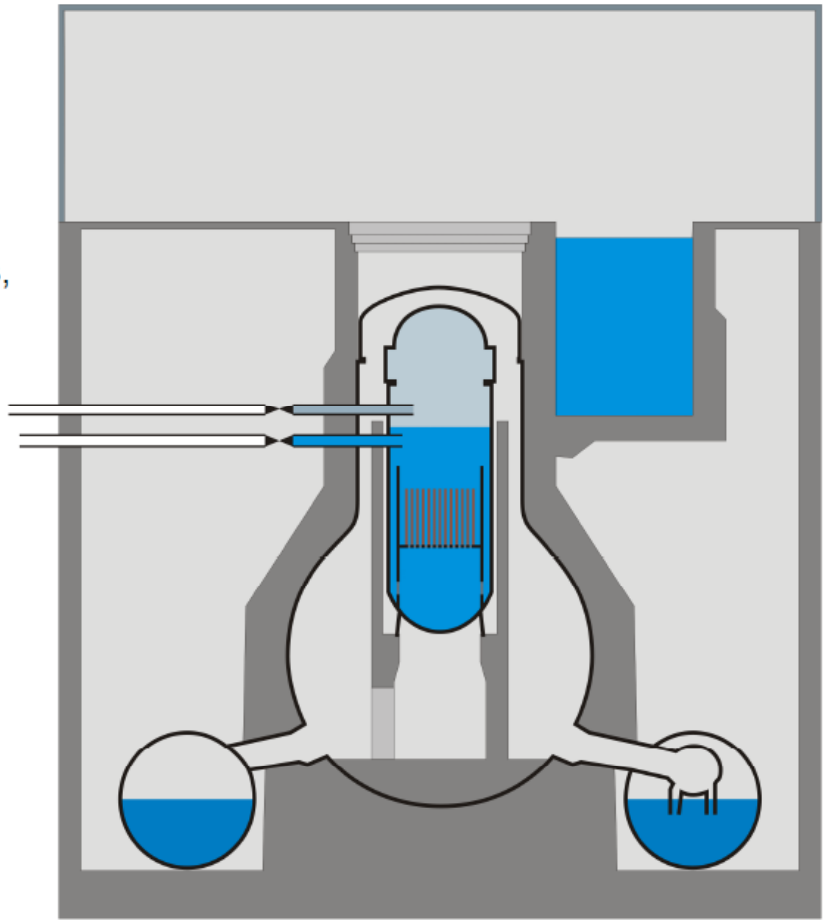
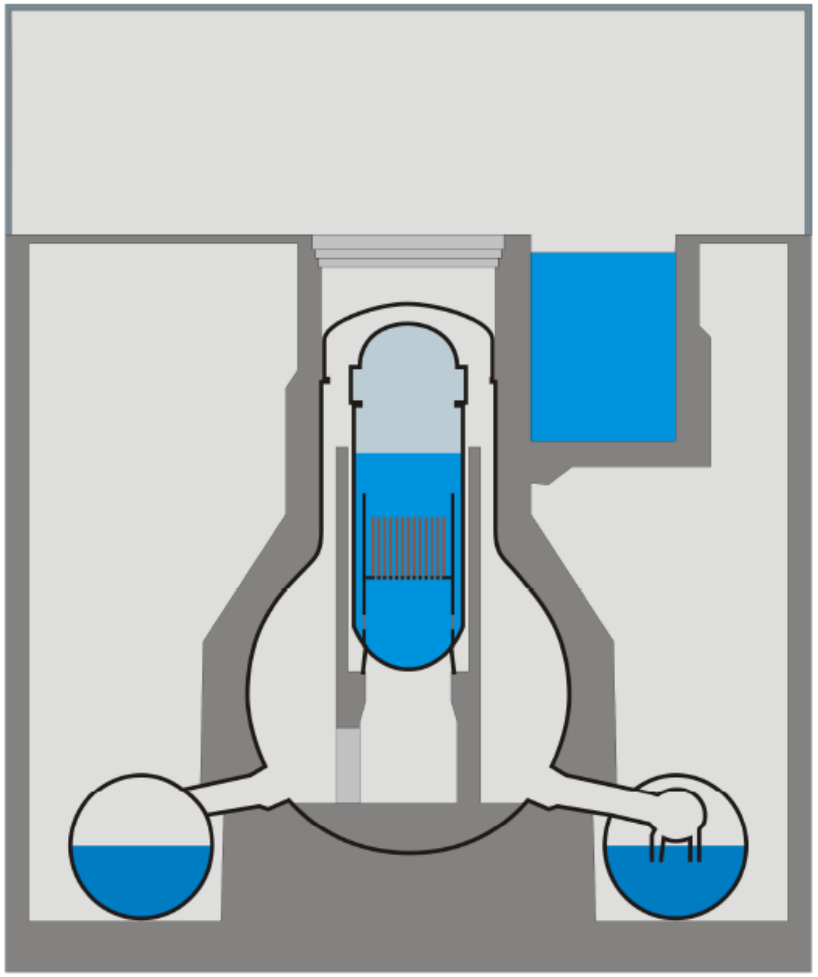
2. Accident Progression

- Containment Isolation
  - Closing of all non-safety related penetrations of the containment
  - Cuts off turbine building
  - If containment isolation succeeds, a large early release of fission products is highly unlikely
- Diesel generators start
  - Emergency core cooling systems are supplied
- Plant is in a stable state



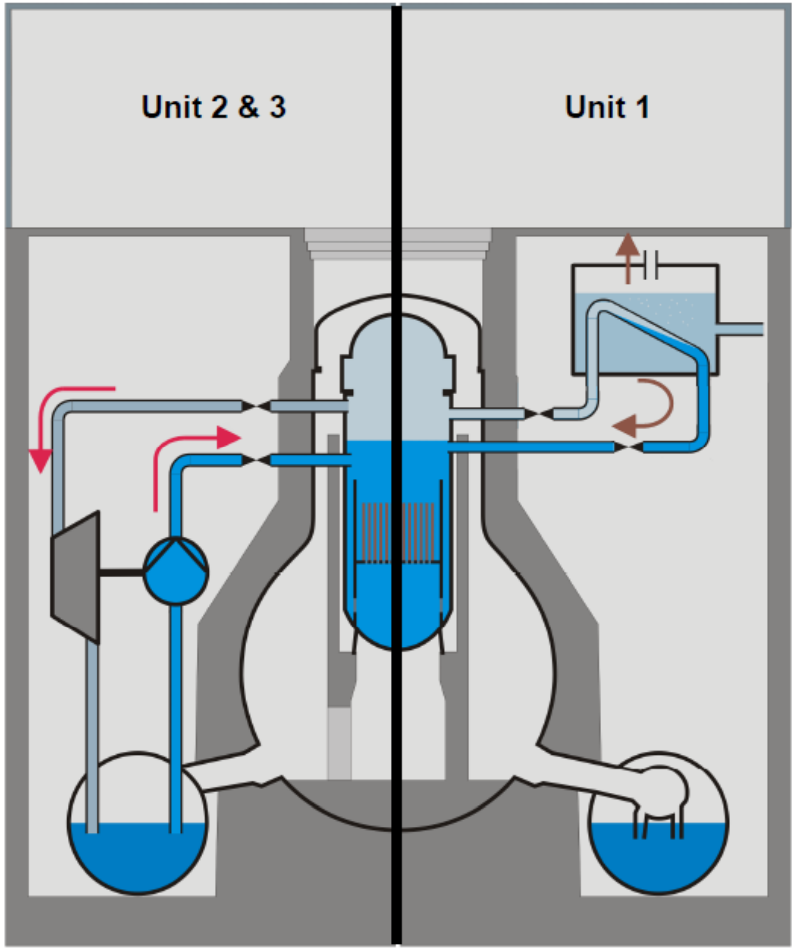
2. Accident Progression

- 11.3. 15:41 Tsunami hits the plant
  - Plant design for tsunami height of up to 5.7m, protection 6.5m
  - Actual tsunami height ~14m
  - Flooding of
    - Diesel generators and/or
    - Essential service water building
- Station Blackout
  - Common cause failure of the power supply
  - Only batteries are available
  - Loss of all emergency core cooling systems, only the steam driven containment isolation pump is available



2. Accident Progression

- Fukushima I Unit 1
  - Isolation Condenser
    - Steam enters heat exchanger
    - Condensate drains back to reactor pressure vessel
    - Secondary steam released from plant
  - Need pumps for water supply
- Fukushima I Unit 2 and 3
  - Reactor Core Isolation Pump
    - Steam from reactor drives turbine
    - Turbine drives a pump, pumping water from the wet-well in the reactor
    - Steam gets condensed in wet-well
  - Necessary:
    - Battery power
    - Wet-well temperature < 100℃
  - No heat removal from the buildings



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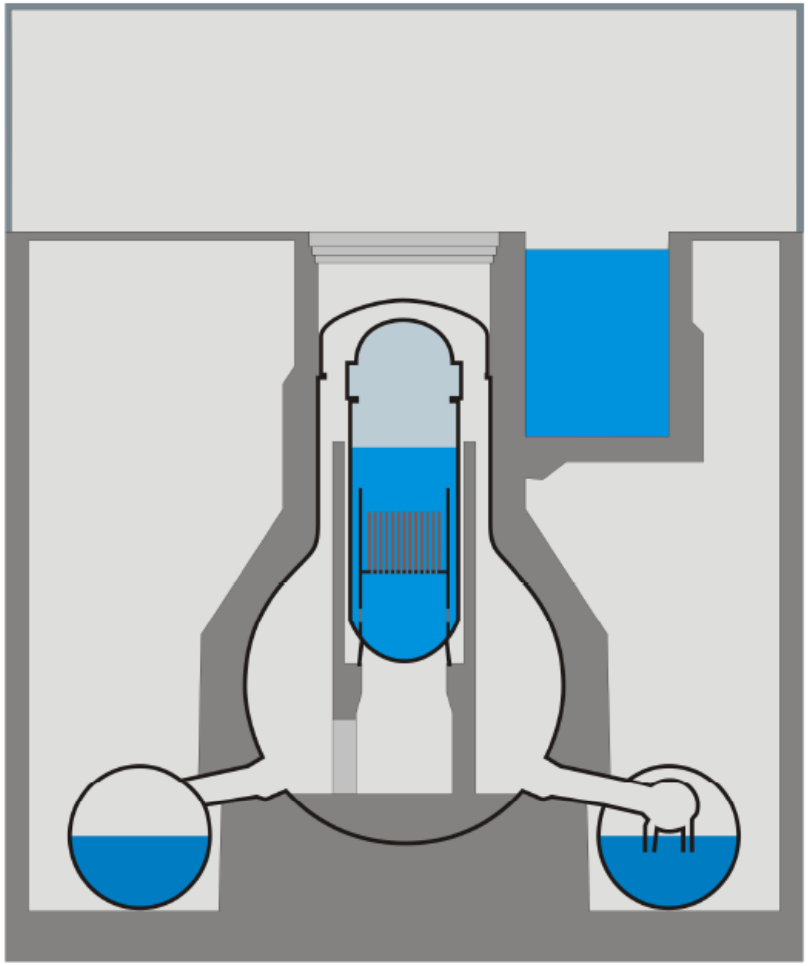
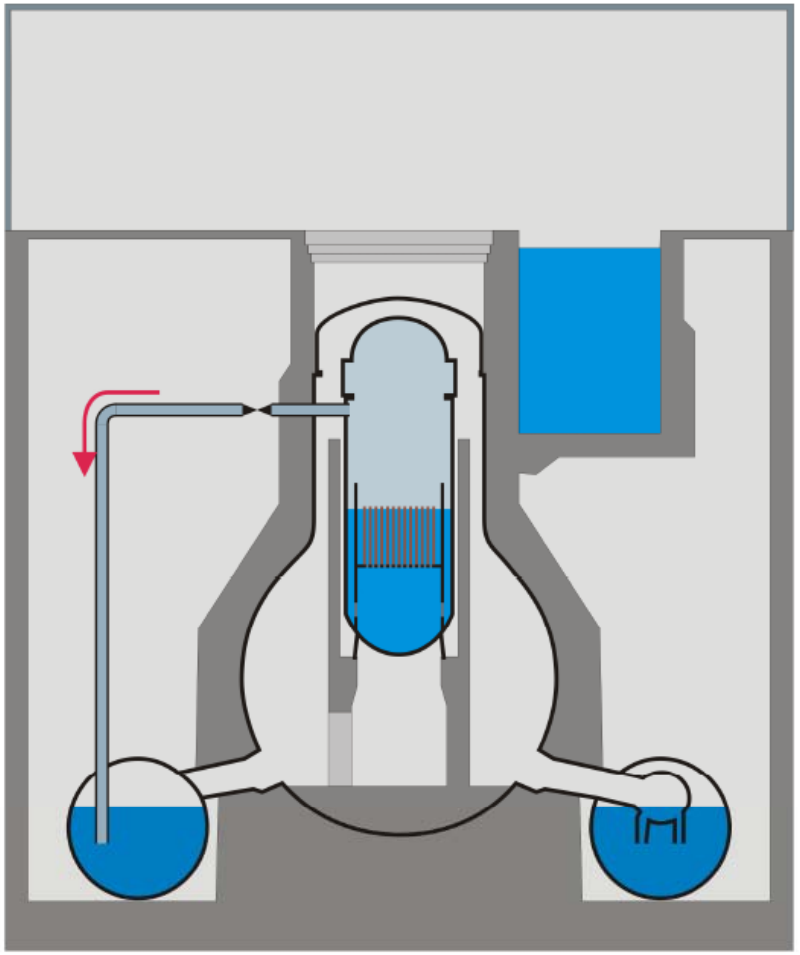
2. Accident Progression

- 11.3. 16:36 in Unit 1
  - Isolation condenser stops
  - Pool empty?
- 13.3. 5:30 in Unit 3
  - Reactor Isolation pump stops
  - Batteries empty?
- 14.3. 13:25 in Unit 2
  - Reactor Isolation pump stops
  - Pump failure?
- Reactors of Units 1-3 are cut off from any kind of heat removal



2. Accident Progression

- Decay heat produces steam in reactor pressure vessel
  - Pressure rising
- Opening the steam relieve valves
  - Discharge steam into the wet-well
- Decreasing of the liquid level in the reactor pressure vessel



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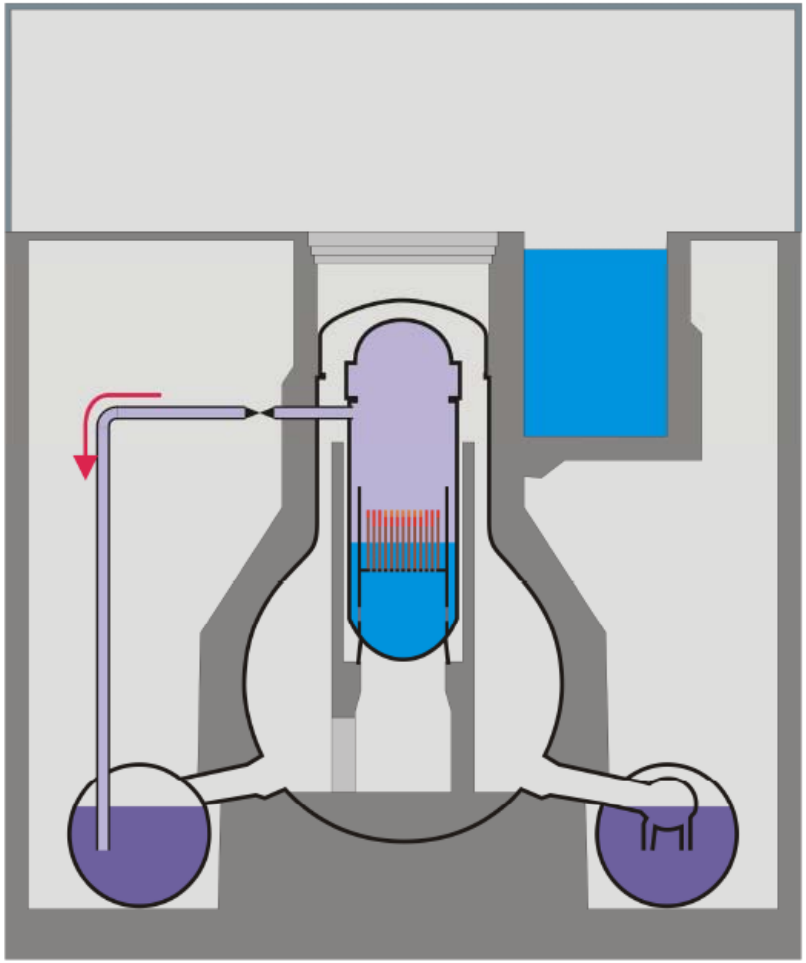
2. Accident Progression

- Measured, and here referenced liquid level is the collapsed level. The swell level is higher due to the steam bubbles in the liquid

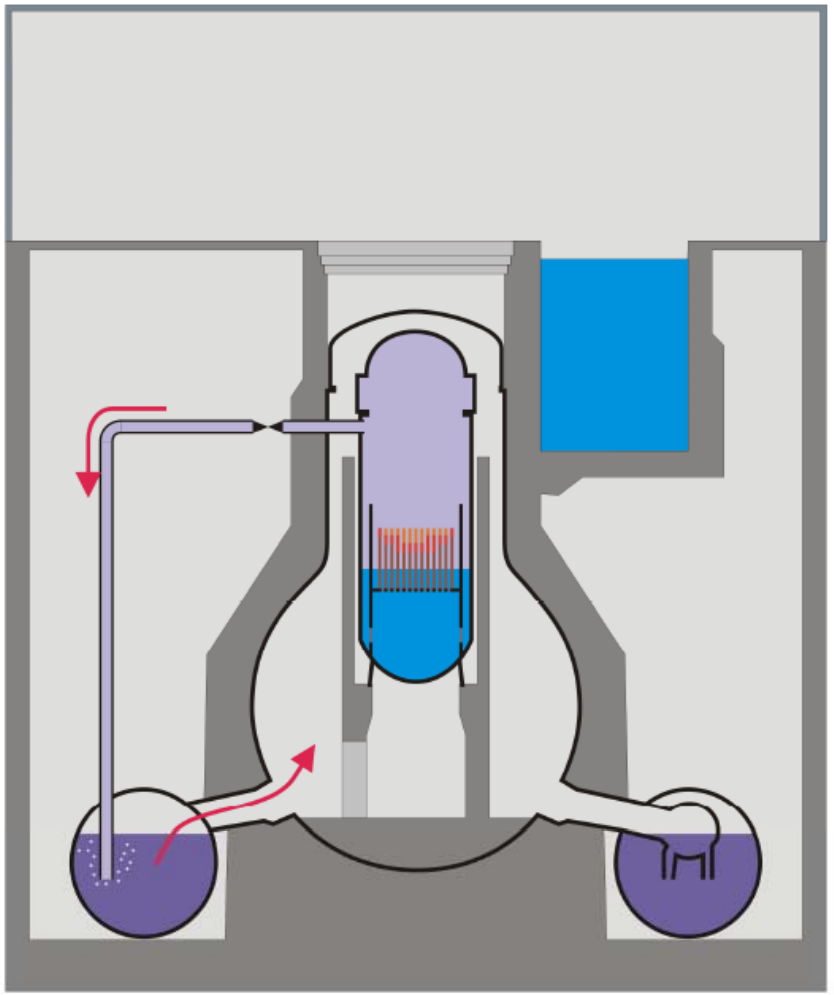
- ~50% of the core exposed
  - Cladding temperatures rise, but still no significant core damage

- ~2/3 of the core exposed
  - Cladding temperature exceeds ~900℃
  - Balooning / Breaking of the cladding
  - Release of fission products from the fuel rod gaps



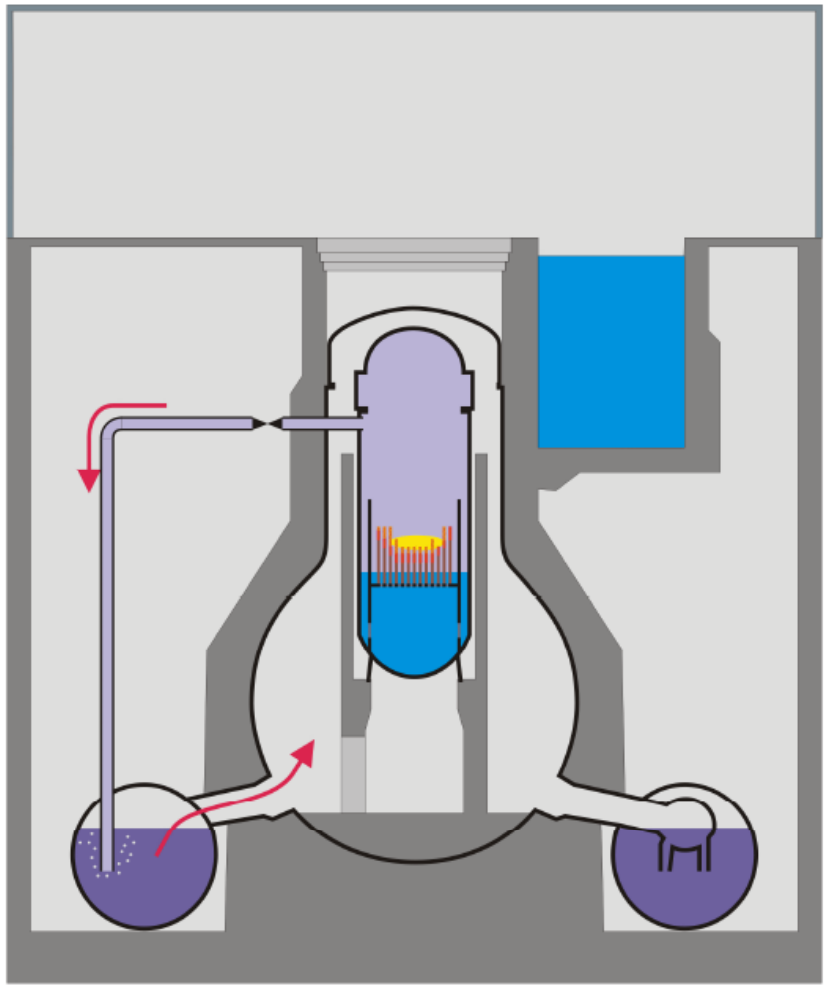
2. Accident Progression

- ~3/4 of the core exposed
  - Cladding exceeds ~1200℃
  - Zirconium water reaction starts under steam atmosphere
  - **$Zr + 2H_20 \rightarrow ZrO_2 + 2H_2$**
  - Exothermal reaction heats the core additionally
  - Generation of hydrogen
    - Unit 1: 300-600kg
    - Unit 2/3: 300-1000kg
  - Hydrogen gets pushed via the wet-well, the wet-well vacuum breakers into the dry-well



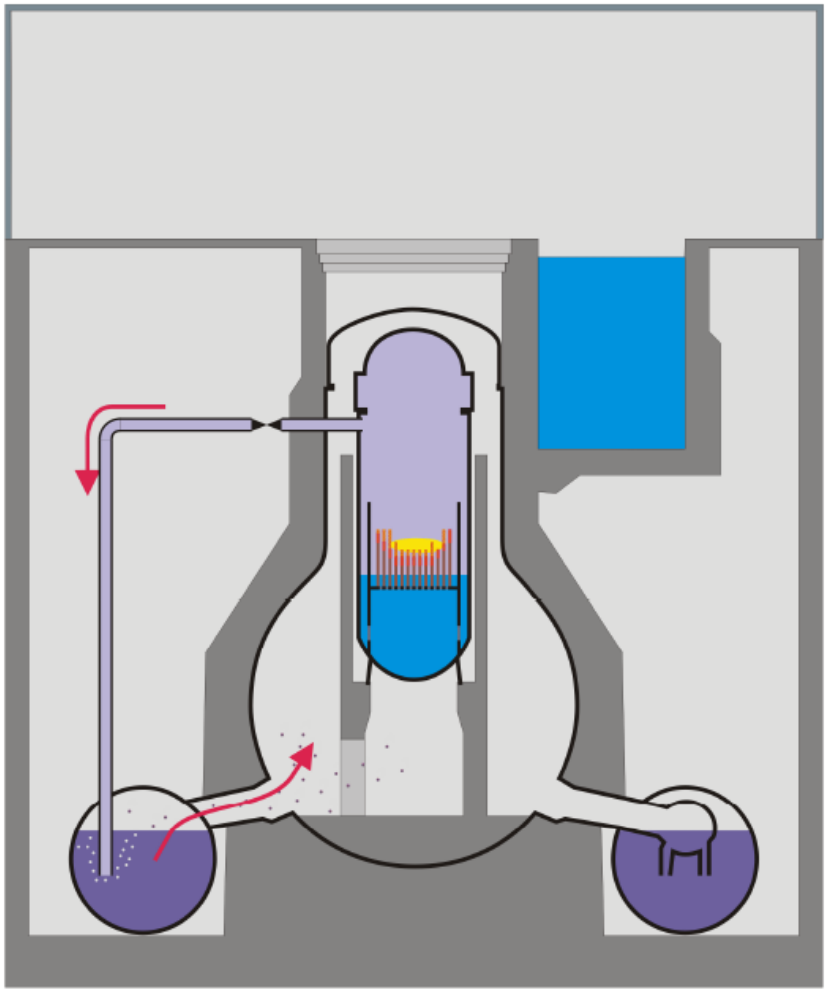
2. Accident Progression

- at ~1800℃ [Unit 1,2,3]
  - Melting of the cladding
  - Melting of the steel structures
- at ~2500℃ [Unit 1,2]
  - Breaking of the fuel rods
  - debris bed inside the core
- at ~2700℃ [Unit 1]
  - Melting of Uranium-Zirconium eutectics
- Supply of seawater to the reactor pressure vessel stops the core melt in all 3 Units
  - Unit 1: 12.3. 20:20 (27h w/o water)
  - Unit 2: 14.3. 20:33 (7h w/o water)
  - Unit 3: 13.3. 9:38 (7h w/o water)



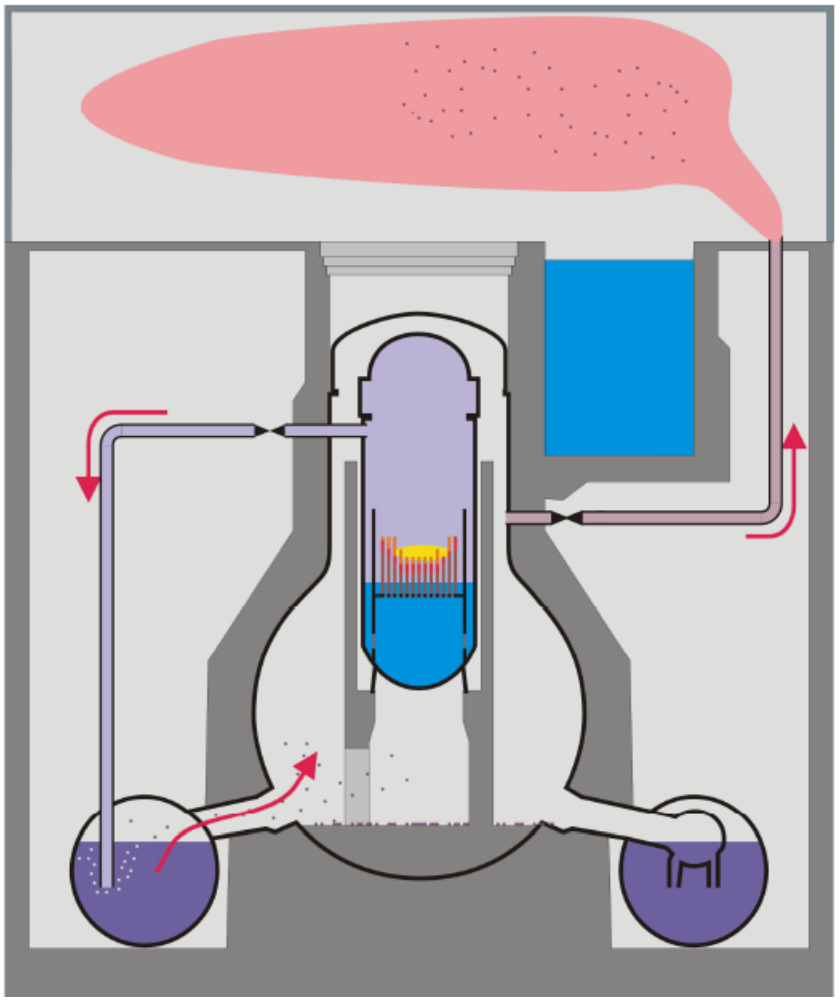
2. Accident Progression

- Release of fission products during melt down
  - Xenon, Cesium, Iodine,…
  - Uranium/Plutonium remain in the core
  - A part of the fission products condensate to airborne aerosols
- Discharge through valves into water of the condensation chamber
  - Pool scrubbing binds a fraction of aerosols in the water
- Xenon and remaining aerosols enter the dry-well
  - Deposition of aerosols on surfaces decontaminates air



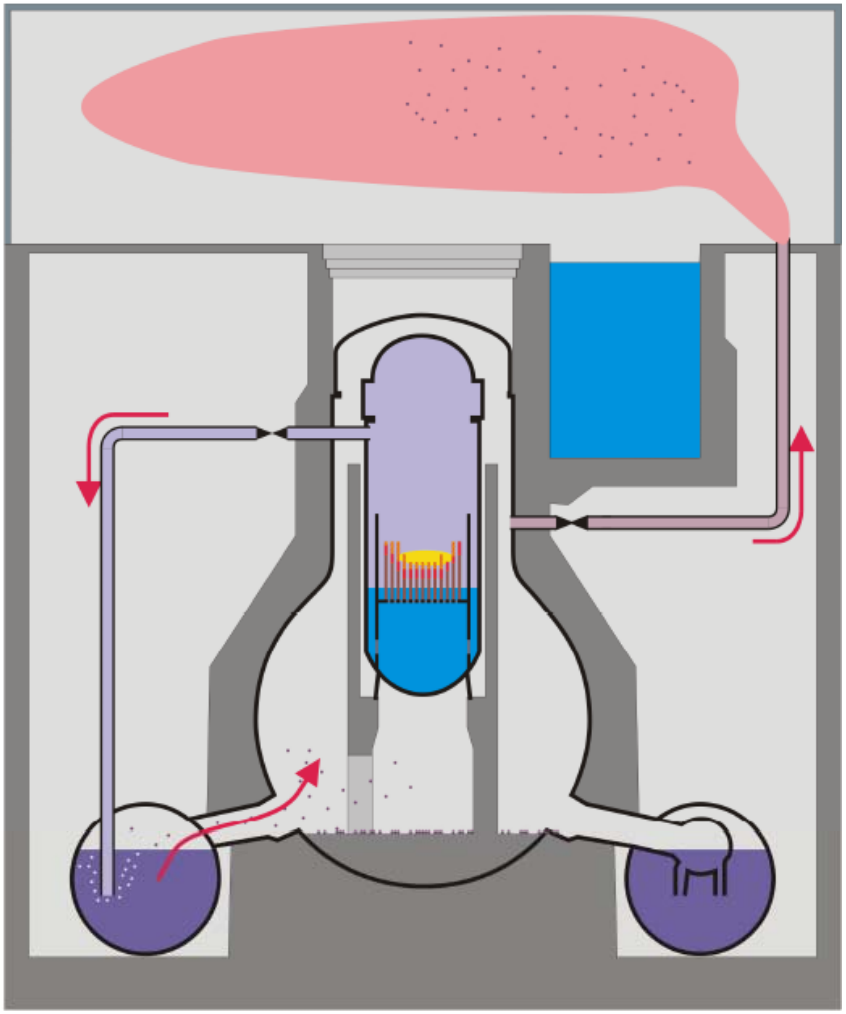
2. Accident Progression

- Containment
  - Last barrier between fission products and environment
  - Wall thickness ~3cm
  - Design pressure 4-5bar
- Pressure reached up to 8 bars
  - Normal inert gas filling (Nitrogen)
  - Hydrogen from core oxidation
  - Boiling in the condensation chamber
- Depressurization of the containment
  - Unit 1: 12.3. 4:00
  - Unit 2: 13.3 00:00
  - Unit 3: 13.3. 8:41



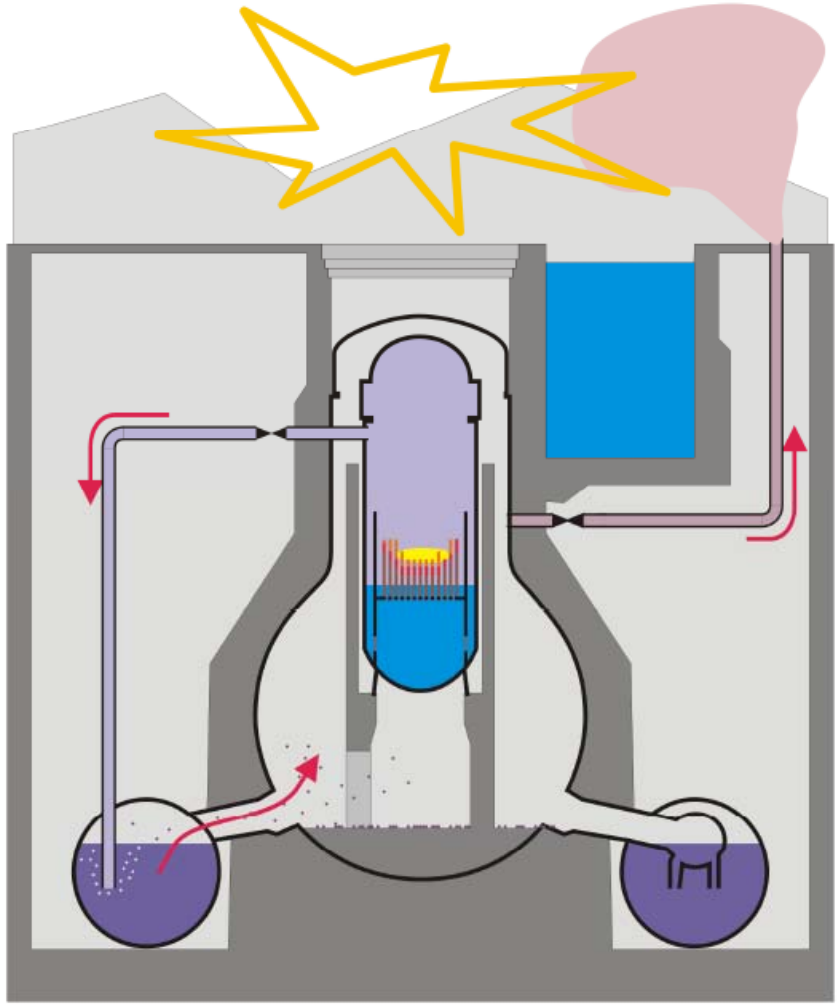
2. Accident Progression

- Positive und negative aspects of depressurizing the containment
  - Removes energy from the containment (the only way left)
  - Reducing the pressure to ~4 bar
  - Release of small amounts of aerosols (Iodine, Cesium ~0.1%)
  - Release of all noble gases
  - Release of hydrogen
- Gas is released into the reactor service floor



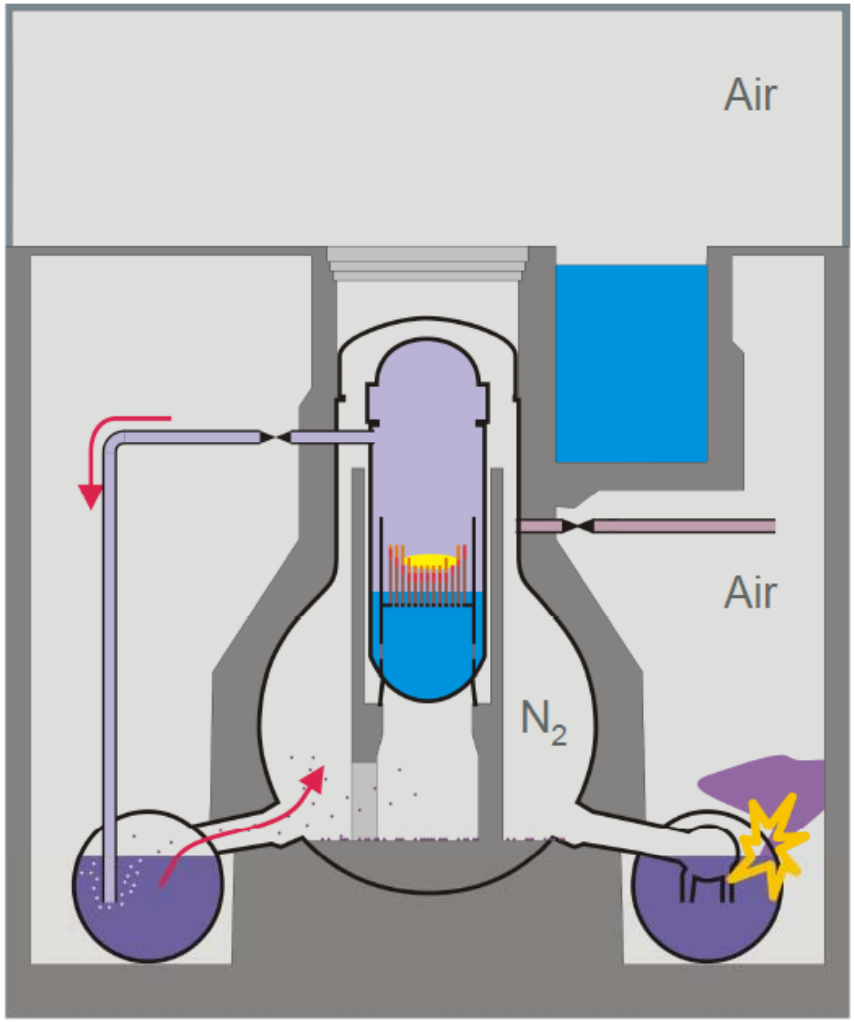
2. Accident Progression

- Unit 1 and 3
  - Hydrogen explosion inside the reactor service floor
  - Destruction of the steel-frame construction
  - Reinforced concrete reactor building seems undamaged



2. Accident Progression

- Unit 2
  - Probably damage of the condensation chamber following a pressure increase in the reactor pressure vessel and containment (highly contaminated water)
  - Uncontrolled release of gas and **fission products** from the containment
  - Temporal evacuation of the plant
  - High local dose rates on the plant site



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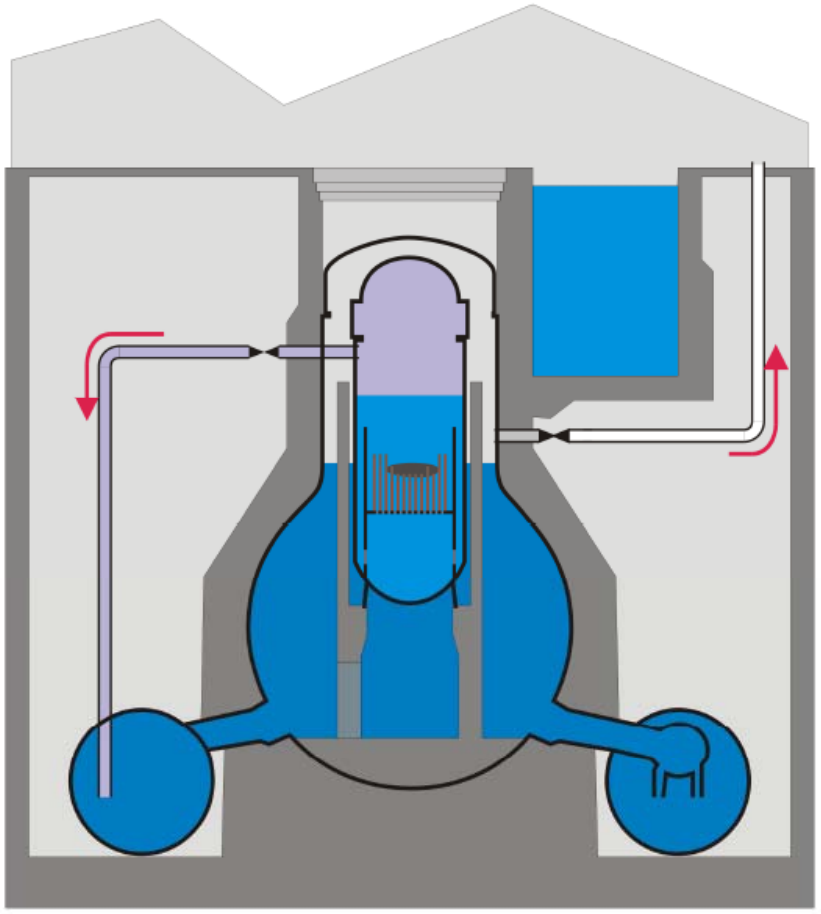
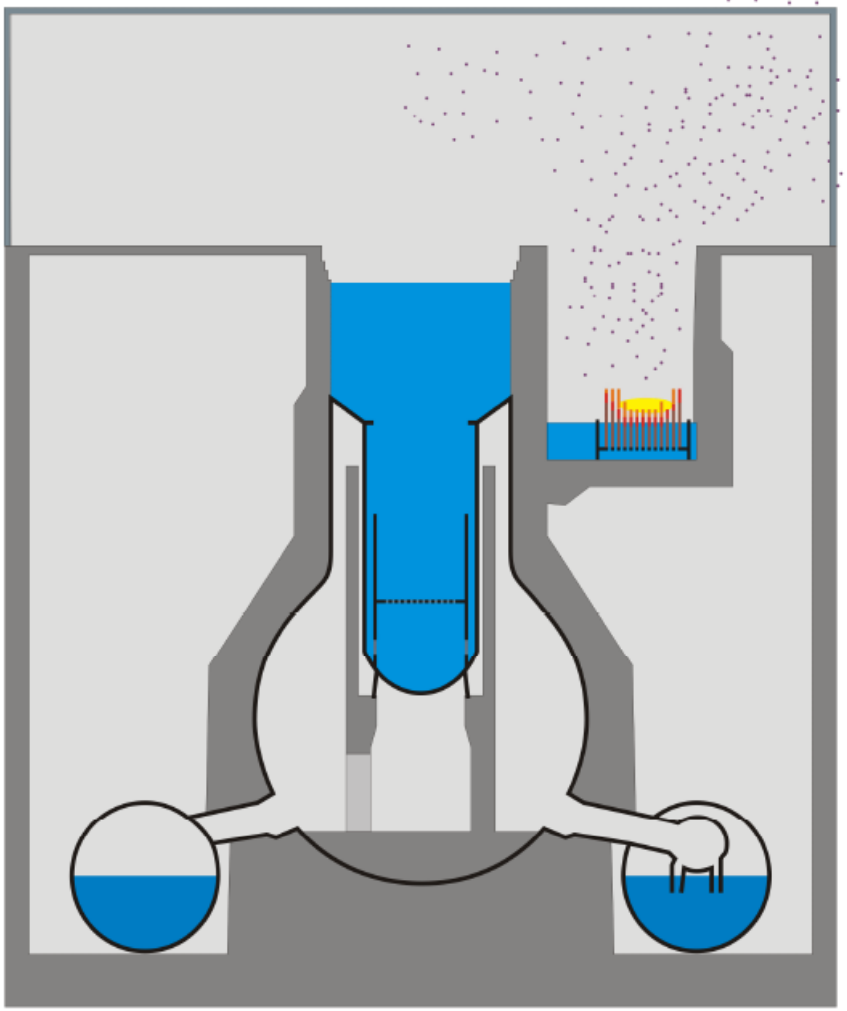
2. Accident Progression

- Current status of the reactors
  - Core damage in Unit 1, 2, 3
  - Building damages of Unit 1-4
  - Reactor pressure vessels feeding with seawater in all units by mobile pumps
  - Containment in Unit 1 flooded



3. Spent Fuel Pools

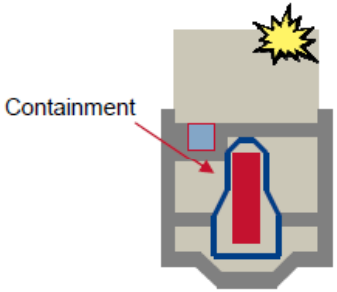
- Spent fuel stored in pool on reactor service floor
  - Due to maintenance in Unit 4 entire core stored in fuel pool
  - Dry-out of the pools
    - Unit 4: in 10 days
    - Unit 1-3,5,6 in few weeks
  - **Leakage of the pools due to Earthquake?**
- Consequences
  - Fuel melt in direct contact to the atmosphere
  - Nearly no retention of fission products
  - Large release possible



Update 22/3 08:00

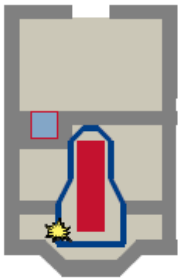
4. Current Status

Units 1 and 3



- Containment and RPV[1] intact
- Partial core meltdown
- Reactor service floor damaged
- Situation stabilised (ongoing cooling by spraying from outside)
- Unit 1 and 3 are connected to the external grid

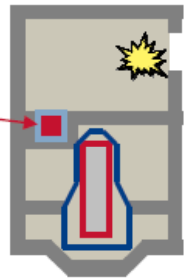
Unit 2



- Containment slightly damaged
- Partial core meltdown
- Reactor service floor damaged
- RPV intact
- Ongoing cooling to avoid leakage of RPV
- Feed of seawater in the spent fuel pool started on March, 20th 2011
- Unit 2 is connected to the external grid

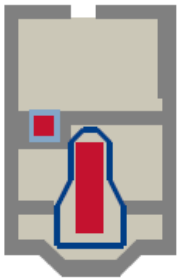
Units in operation at the time of the earthquake

Unit 4



- Core completely in the spent fuel pool
- Reactor service floor damaged
- Status of the water level in the spent fuel pool unknown
- Cooling of the spent fuel pool difficult
- Preparation for reconnection to the external grid

Units 5 and 6



- Core partially in the spent fuel pool
- Temperature in the spent fuel pool stable at 30℃ resp. 35 ℃
- Status of the reactor "cold, subcritical"
- Open a vent hole on the rooftop for avoiding hydrogen explosion

Units shutdown at the time of the earthquake

[1] Reactor pressure vessel
Note: All timing information in GMT+1

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Reactor 1 and 3 events

Accident progression

11.3.2011 Kl. 14:46

Earthquake magnitude 9.0
Power failure in northern Japan

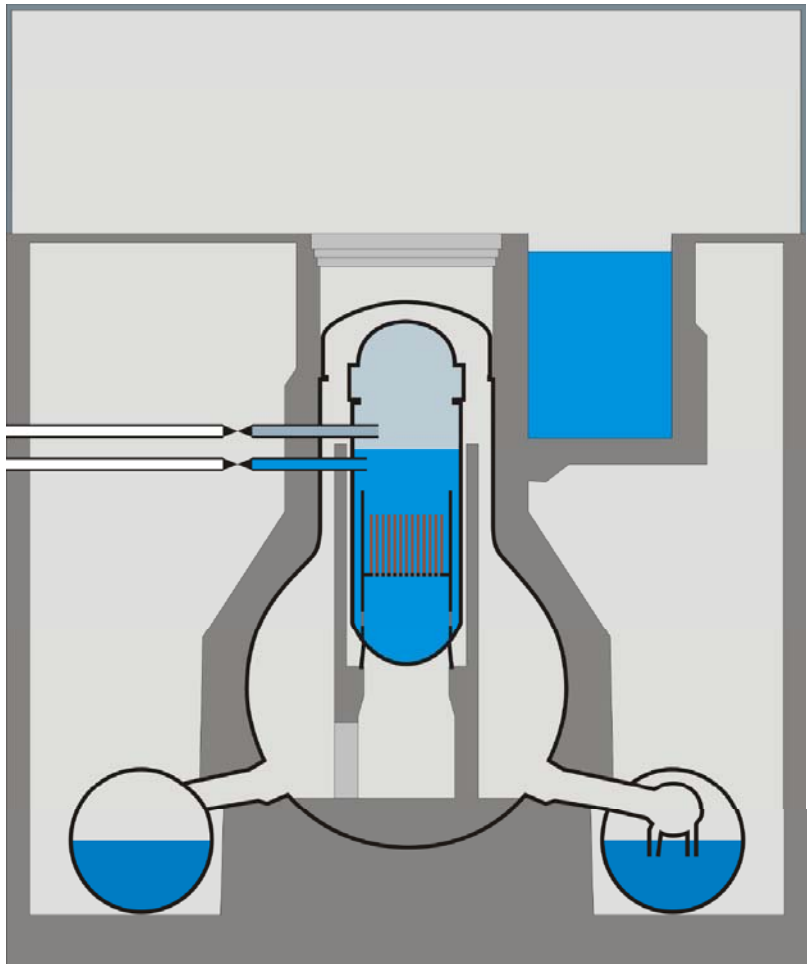
Reactors 1-3 automatic SCRAM, chain reaction stops

Decay Heat generation:

1 sec.	~ 6 %
1 day	~ 1 %
1 week	~ 0.5 %

Diesel generators start

Power plant in stable state



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3-4. Chronology of Unit 1 after the earthquake

● *Unit 1*

11th
- ●Under operation, Automatic shutdown by the earthquake
- ●Loss of A/C power
- ●Loss of water injection function

12th
- ●Unusual increase of PCV pressure
- ●Started to vent
- ●Sound of explosion
- ●Started of injection of seawater and borated water to the core

22nd
- ●Rise of reactor temperature (383℃) → Drop (26th 05:00 144.3℃)

23rd
- ●Water supply line in addition to the Fire Extinguish line. Switched to water supply line only.(Flow rate: 7m^3/h)

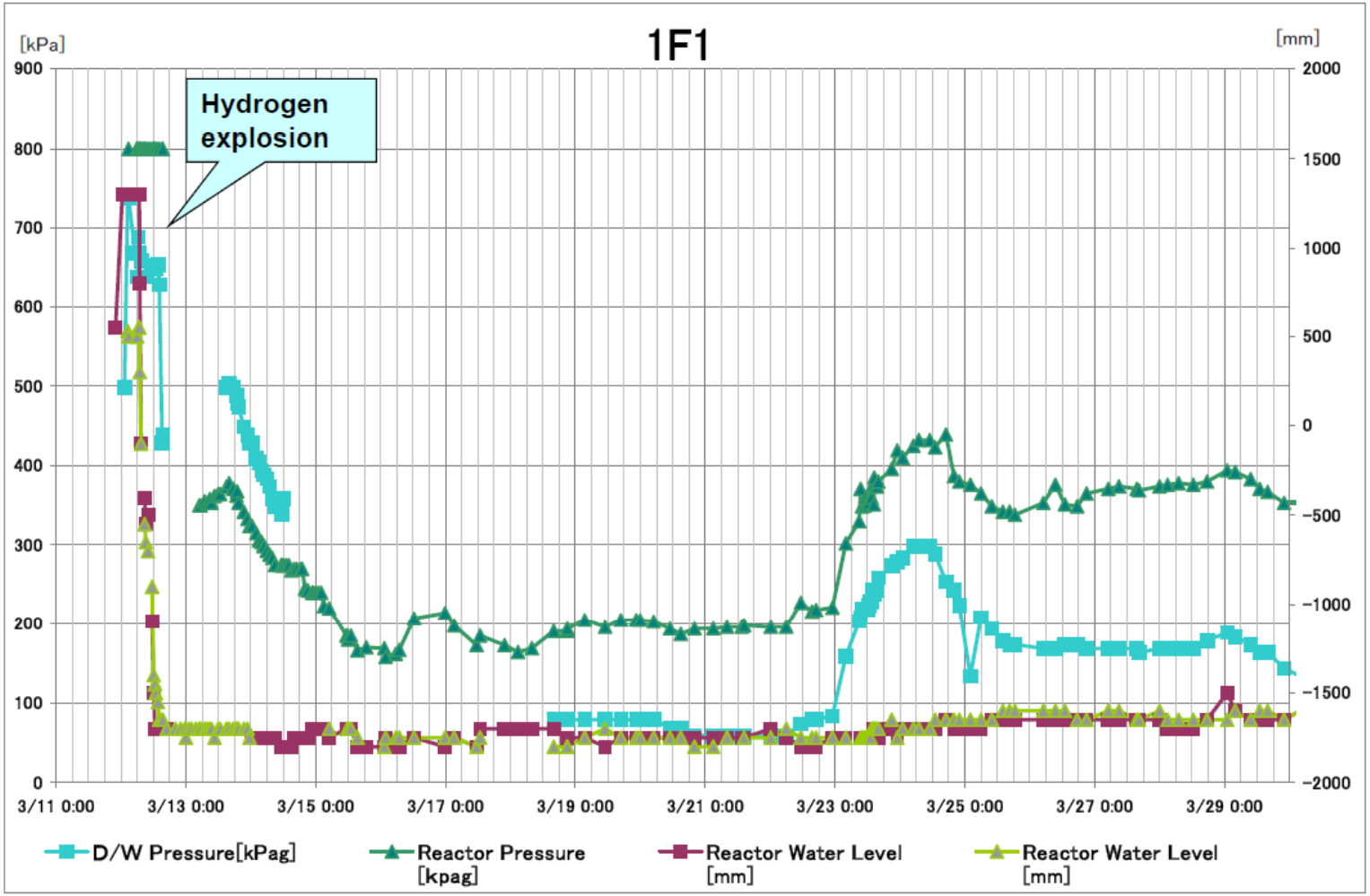
24th
- ●Lighting in the Central Control Room was recovered.

25th
- ●Started fresh water injection

29th
- ●Switched to the water injection to the core using a temporary motor operated pump.

31st
- ●White smoke was confirmed to generate continuously
- ●Freshwater is being injected into the RPV

3-6. Trend data of Unit 1 until March 30



16

Accident progression

11.3.2011 Kl. 15:41

Tsunami hits the plant

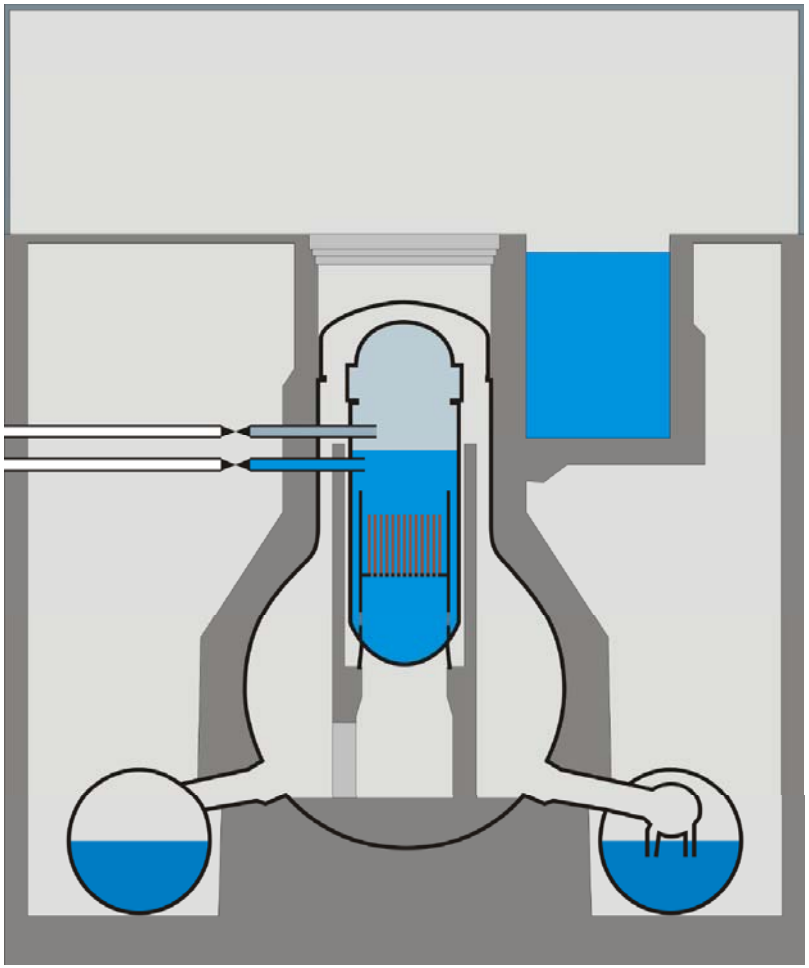
Plant design hight 6,5 m
Tsunami water level ~ 14 m

Turbine hal flooded
Diesel generators failure

Station Blackout

Only batteries available
Insufficient cooling

Power plant unstable
INES level 4



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DTU

Accident progression

11.3.2011 Kl. 16:36

Loss of cooling in unit 1

13.3.2011 Kl. 5:10

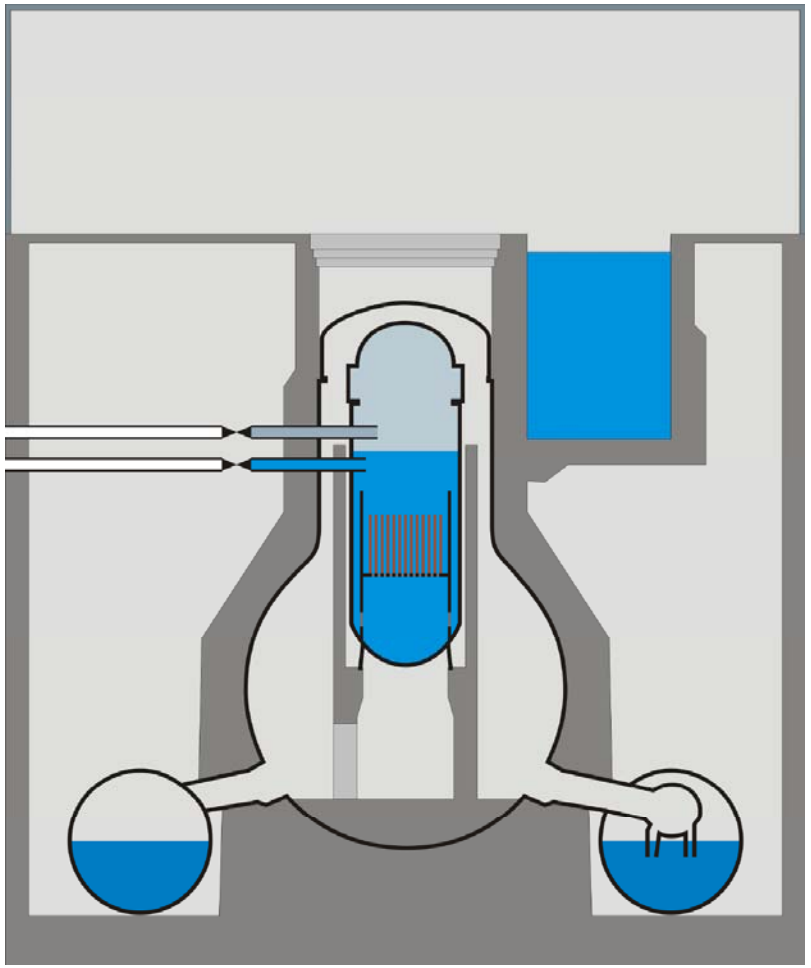
Loss of cooling in unit 3

14.3.2011 Kl. 13:25

Loss of cooling in unit 2

12.3 Evacuation, 20 km zone

Power plant unstable
INES level 4



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Accident progression

12-13.3.2011

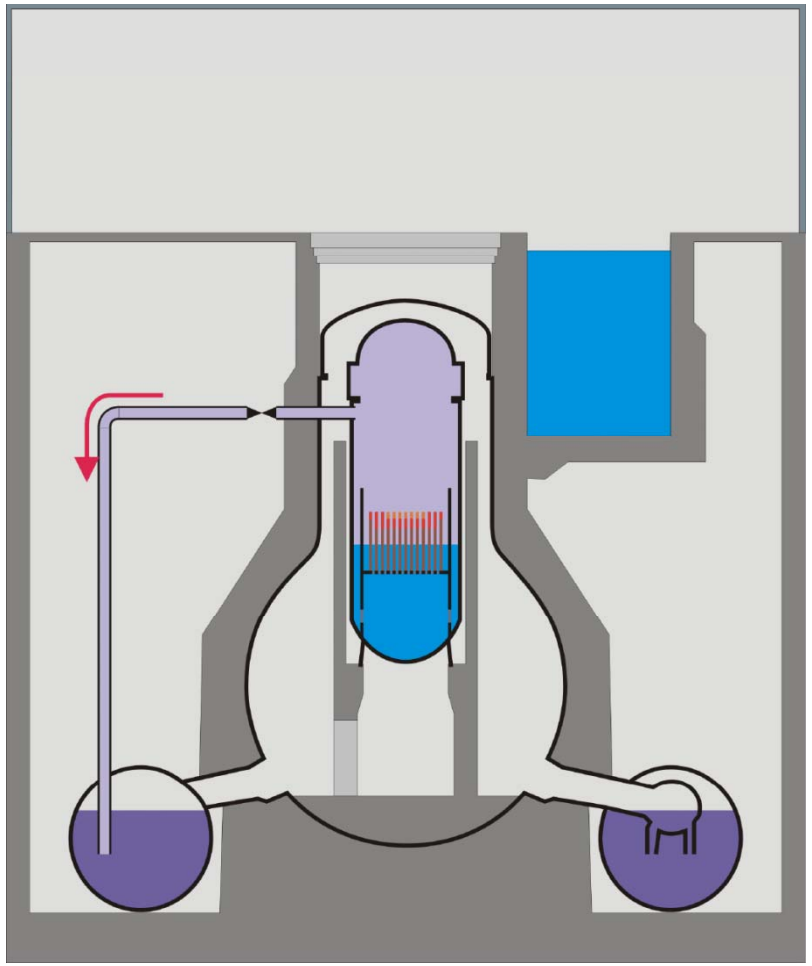
Temperature and pressure raising
Water level decreasing
Pressure release of RPV

Start of melt down

900 °C Release of radioactivity
1200 °C Hydrogen production
1800 °C Fuel cladding melts
2700 °C Fuel (U-Zr) melts

Reactor containment intact

Power plant very unstable
INES level 5



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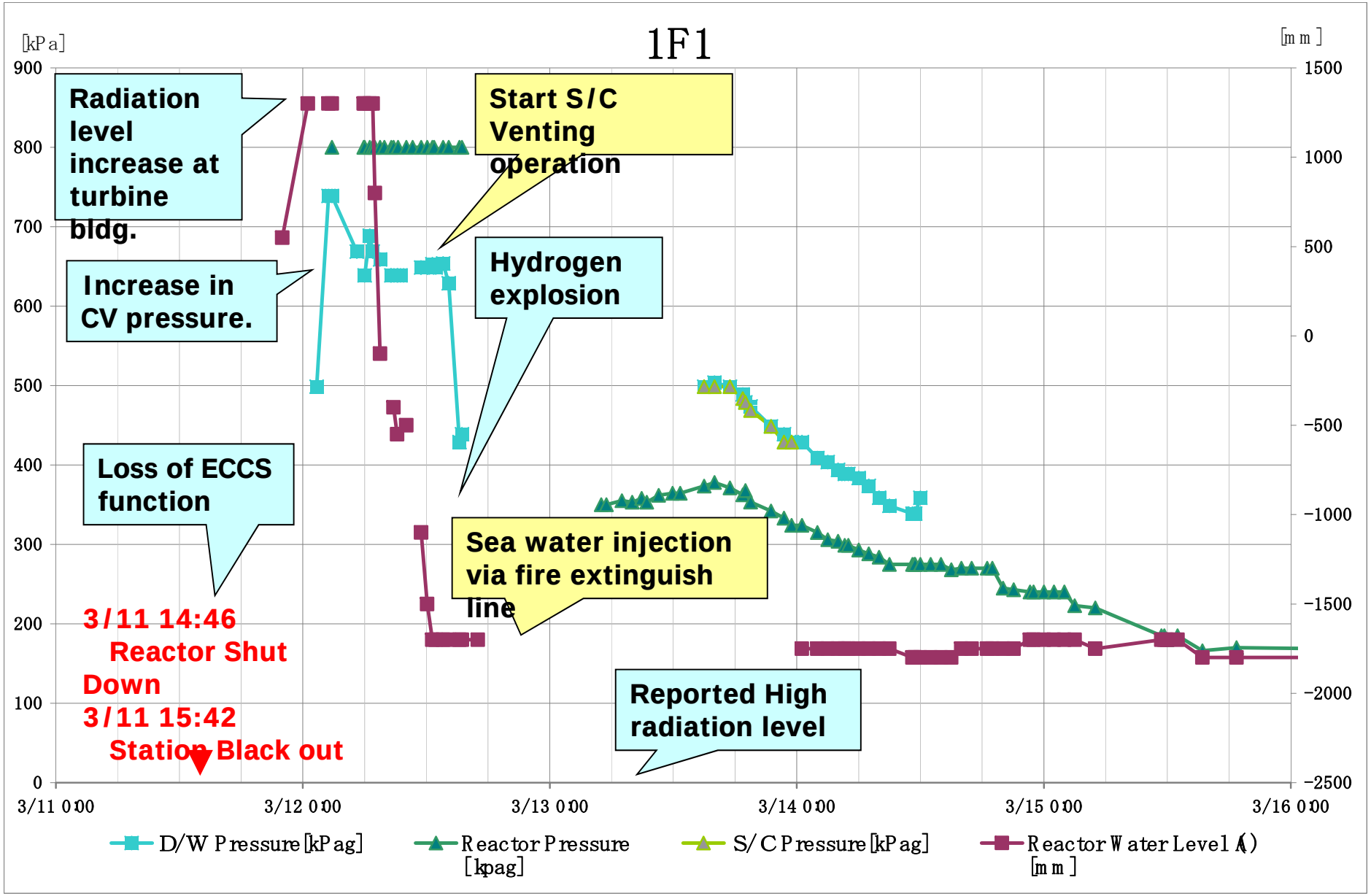
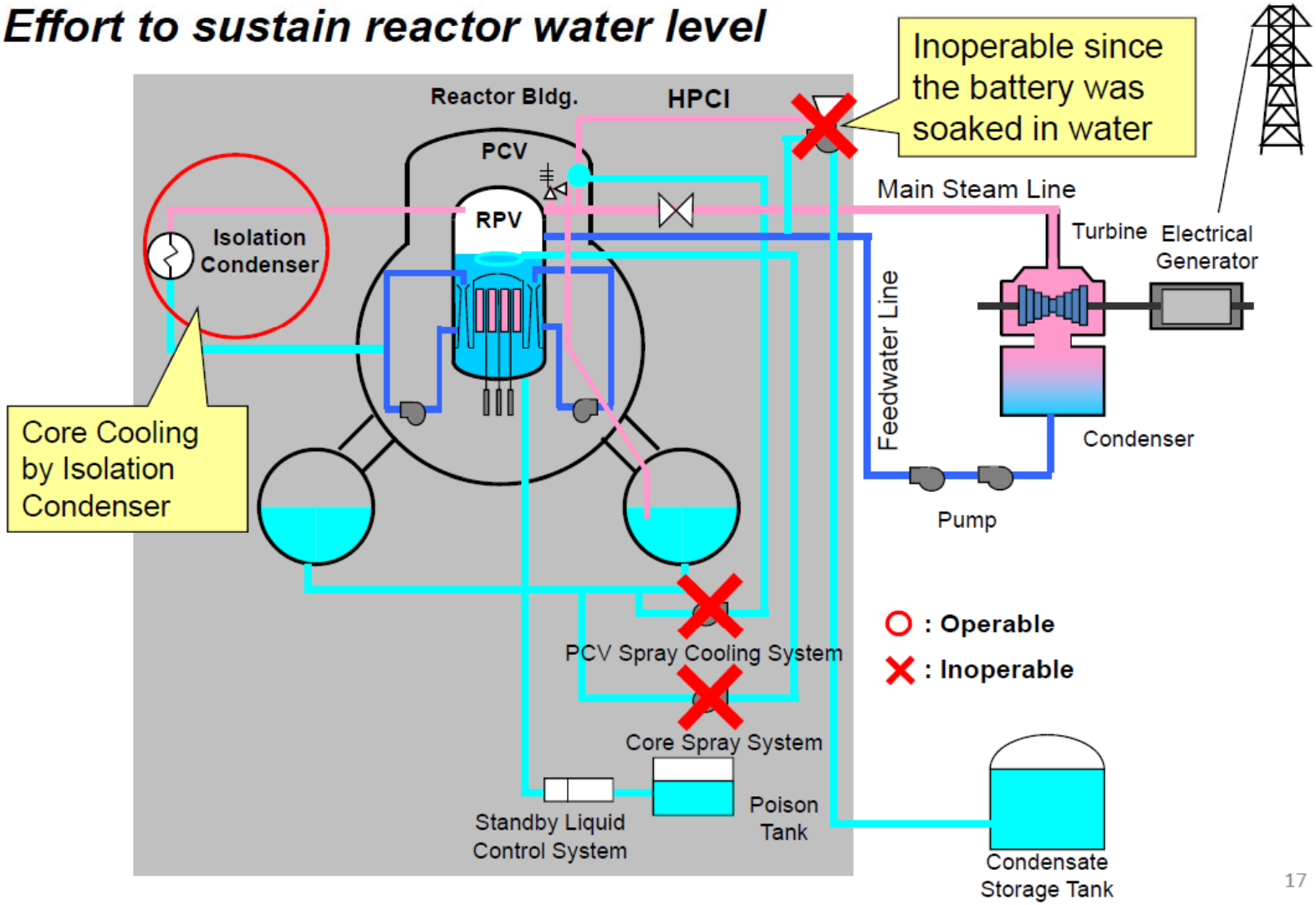
DTU

Reactor 1, old mesurements (with errors!!)



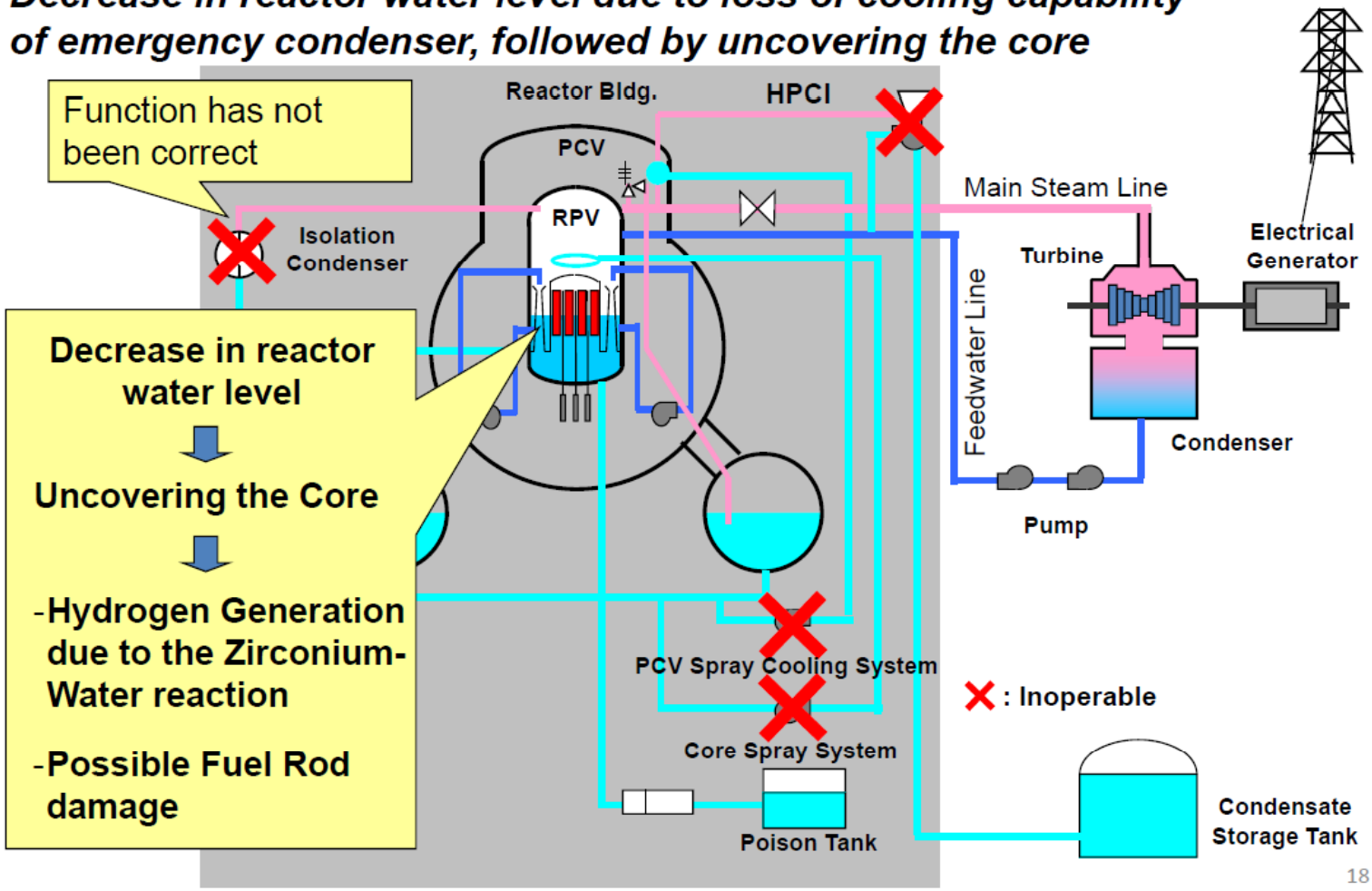
3-7. Major event progression at Unit 1 (1/4)

Effort to sustain reactor water level



3-7. Major event progression at Unit 1 (2/4)

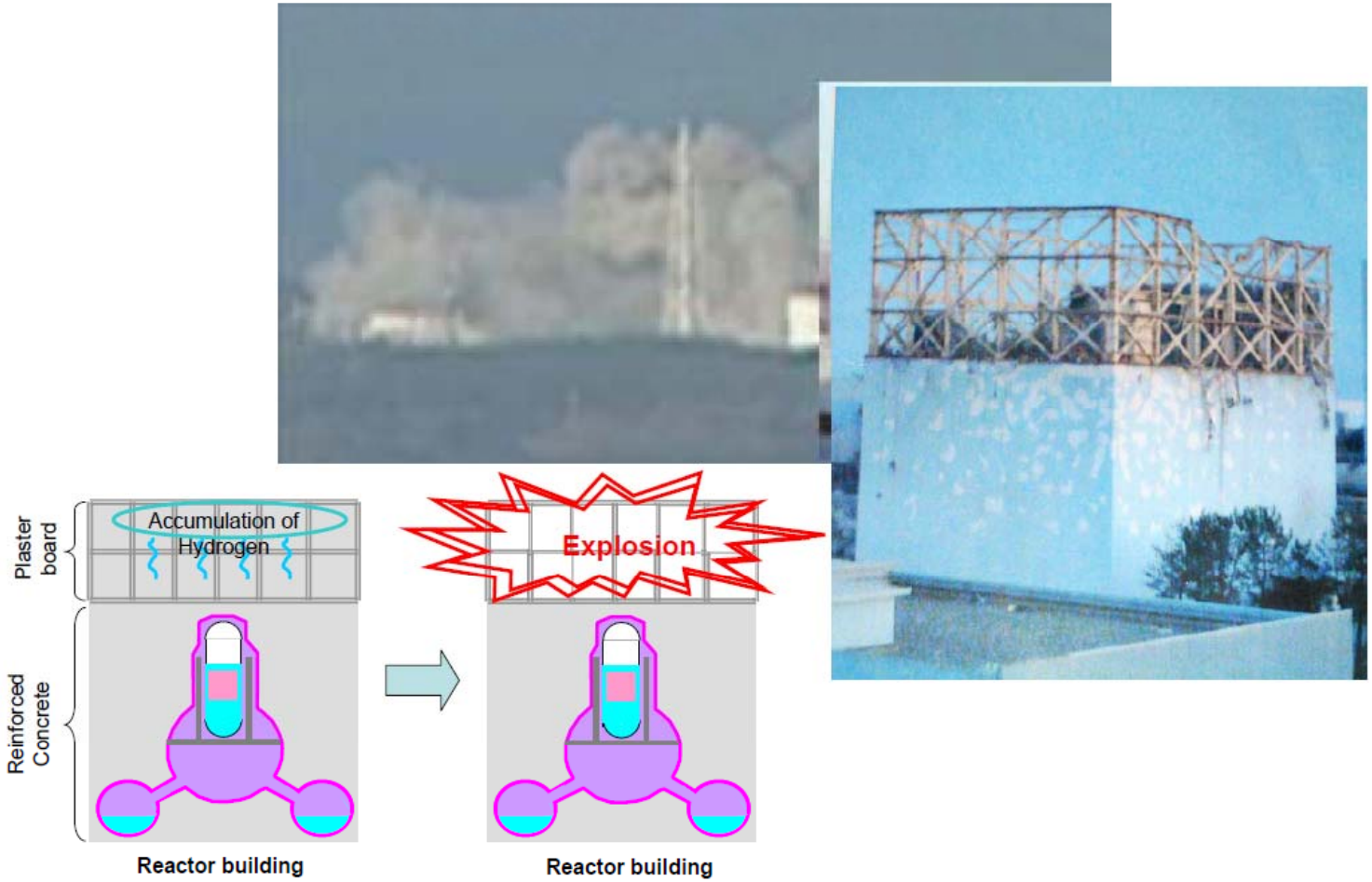
Decrease in reactor water level due to loss of cooling capability of emergency condenser, followed by uncovering the core



18

3-7. Major event progression at Unit 1 (3/4)

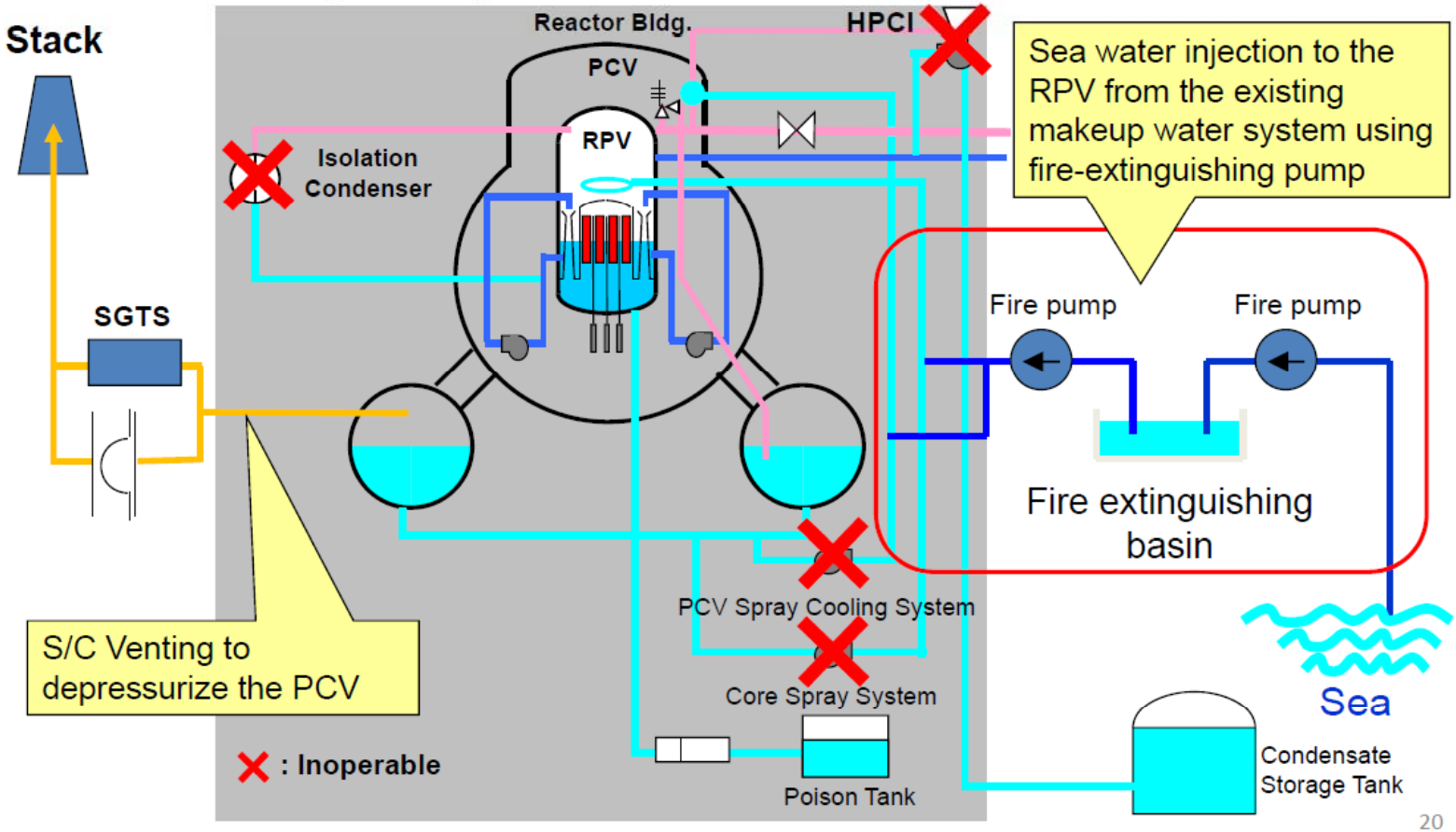
Hydrogen explosion in the operation floor



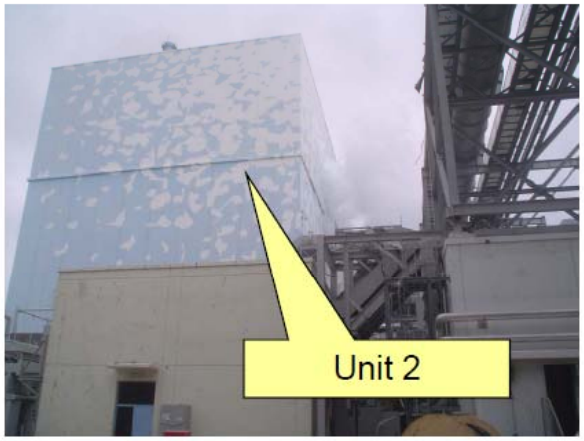
3-7. Major event progression at Unit 1 (4/4)

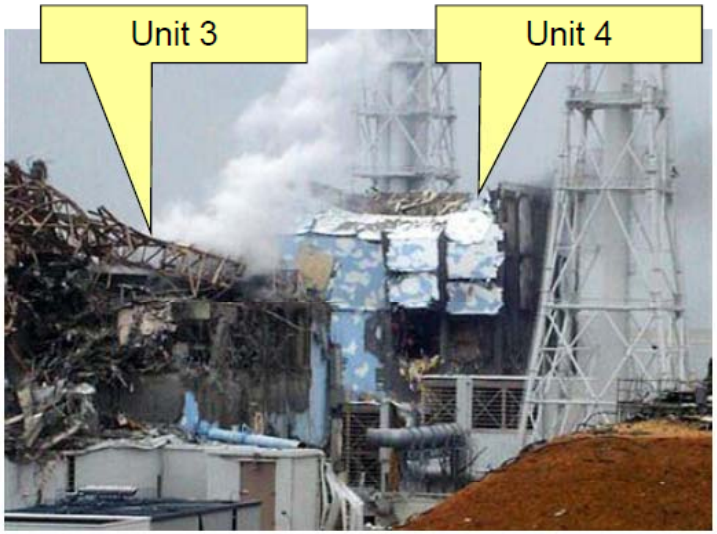
- Sea water injection using fire water pump

- S/C Venting to depressurize the PCV



3-8. Accident Progression at Unit 2 through 4 reactors





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DTU

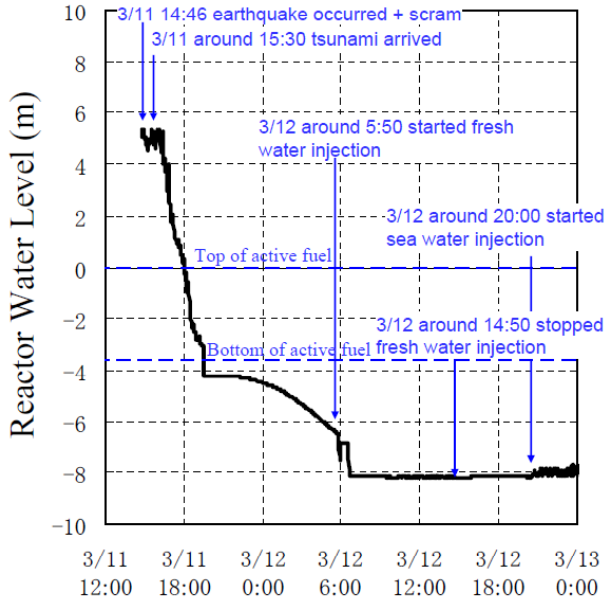
Melted fuel in unit 1

Recirculation, cooling and filtering of water from the bottom of containment

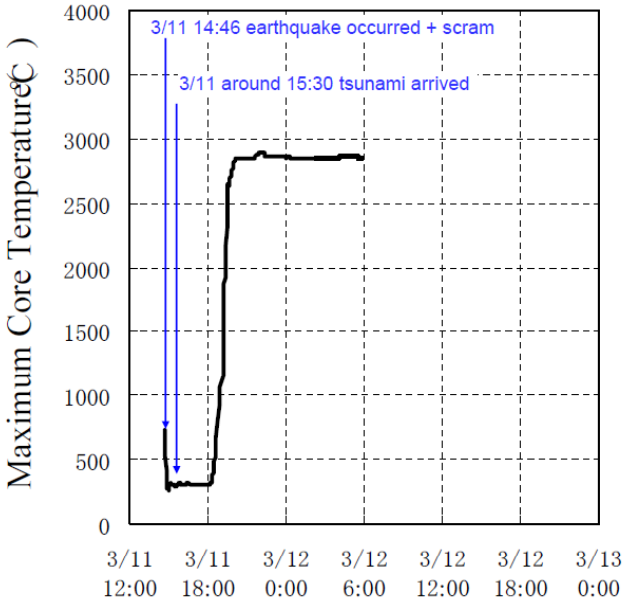
Simulation

Unit 1:Reactor Water Level, Maximum Core Temperature (Analysis Result)

Key assumption: IC lost its function after the tsunami arrived at around 15:30



- reached top of active fuel in 3 hours (around 18:00) after the scram
- reached bottom of active fuel in 4 and a half hours (around 19:30) after the scram



The core temperature started increasing when the reactor water level became lower than top of active fuel, then reached the core melting temperature.

Time and operations described herein might be revised according to the accident investigation in the future.

Core melt progressing unit 1

Unit 1: Transition of Core Status (analysis result)

Degree of fuel damage

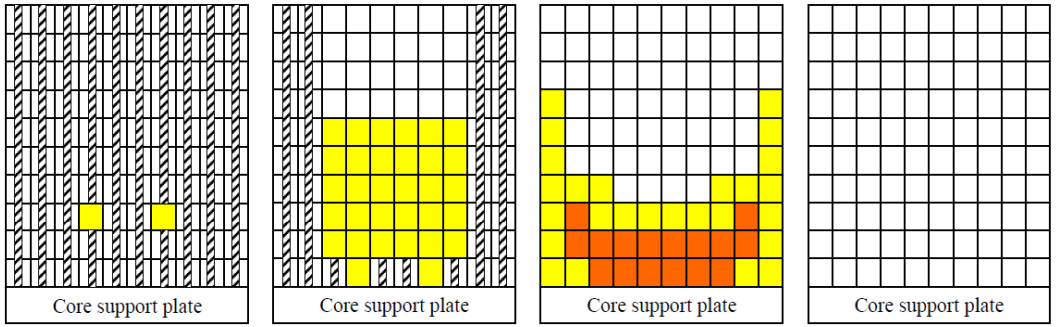
:Normal fuel

:Damaged fuel

:Fuel pellet melted

:Void (fuel melted down)

- Melting starts from the central part of the core.
- In 16 hours after scram (around March 12th 6:50), most part of the core fell down to the RPV bottom.
- Although RPV is damaged in this provisional analysis, the actual damage of RPV is considered to be limited according to the temperatures presently measured around the RPV.



4.8 hours after scram (around March 11th 19:30)

5.1 hours after scram (around March 11th 19:50)

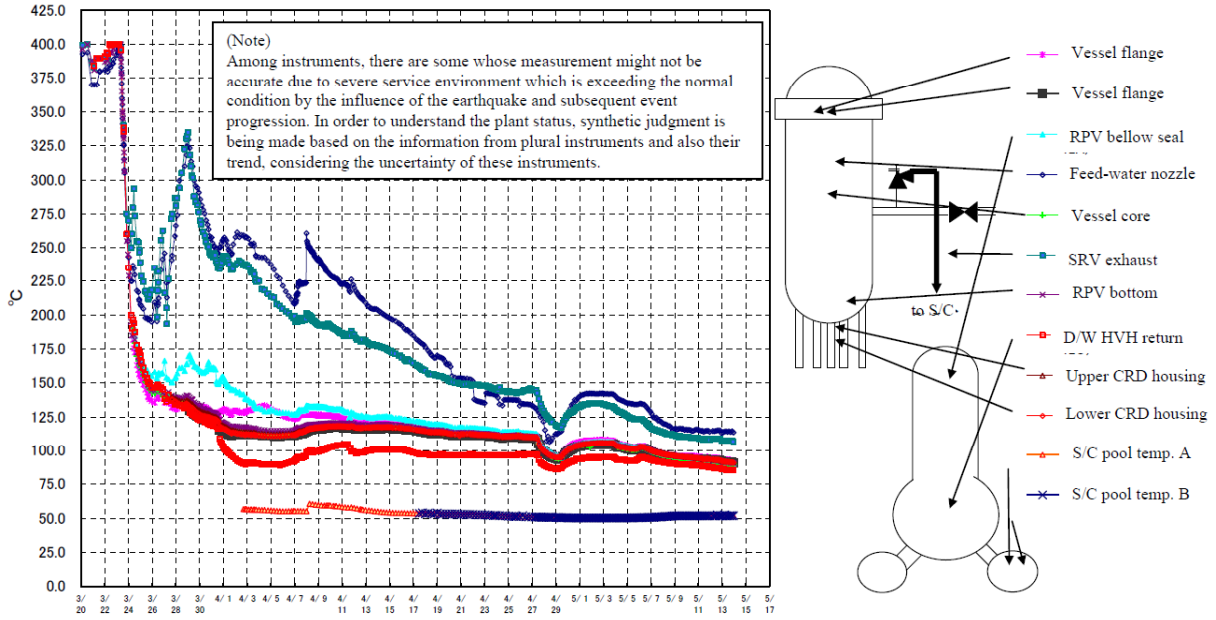
15.1 hours after scram (around March 12th 6:00)

16.0 hours after scram (around March 12th 6:50)

3

Measured RPV temperatures

Unit 1: Temperatures around RPV (actual measurement value)

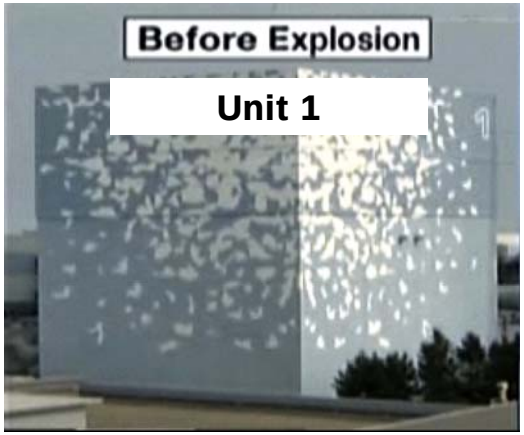


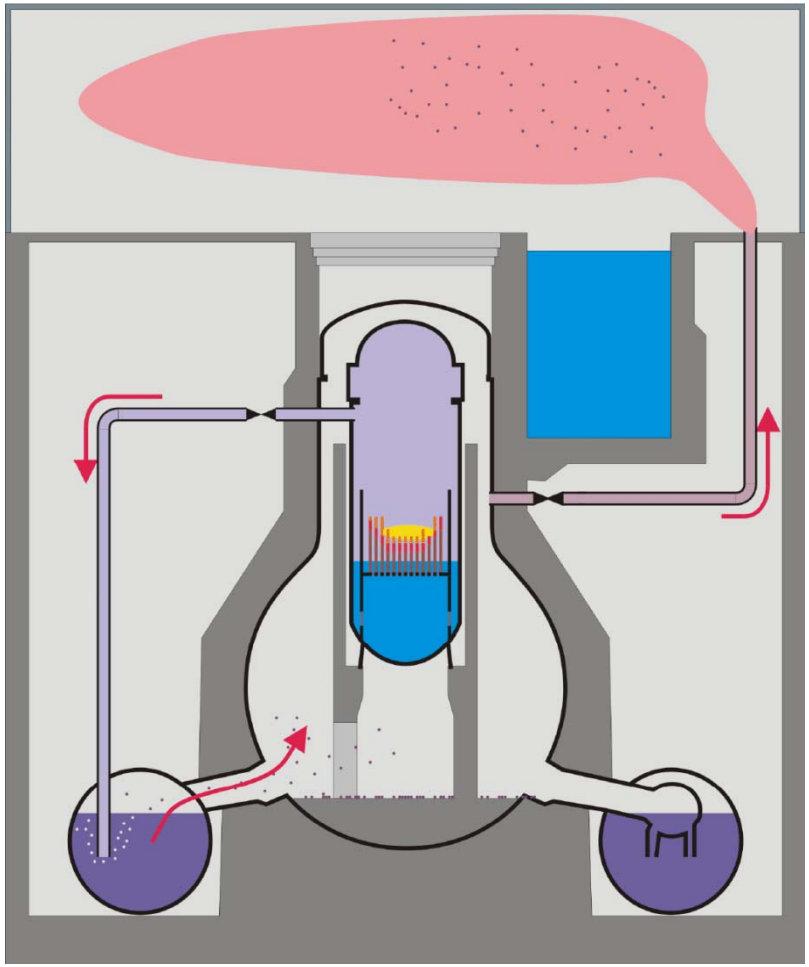
Units 1, 3

12 - 14.3.2011

Radioactive steam in reactor building
Hydrogen in reactor building

Power plant very unstable
INES level 5





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Fukushima NPP after the accident

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Reactor 2-4

Reactor 4

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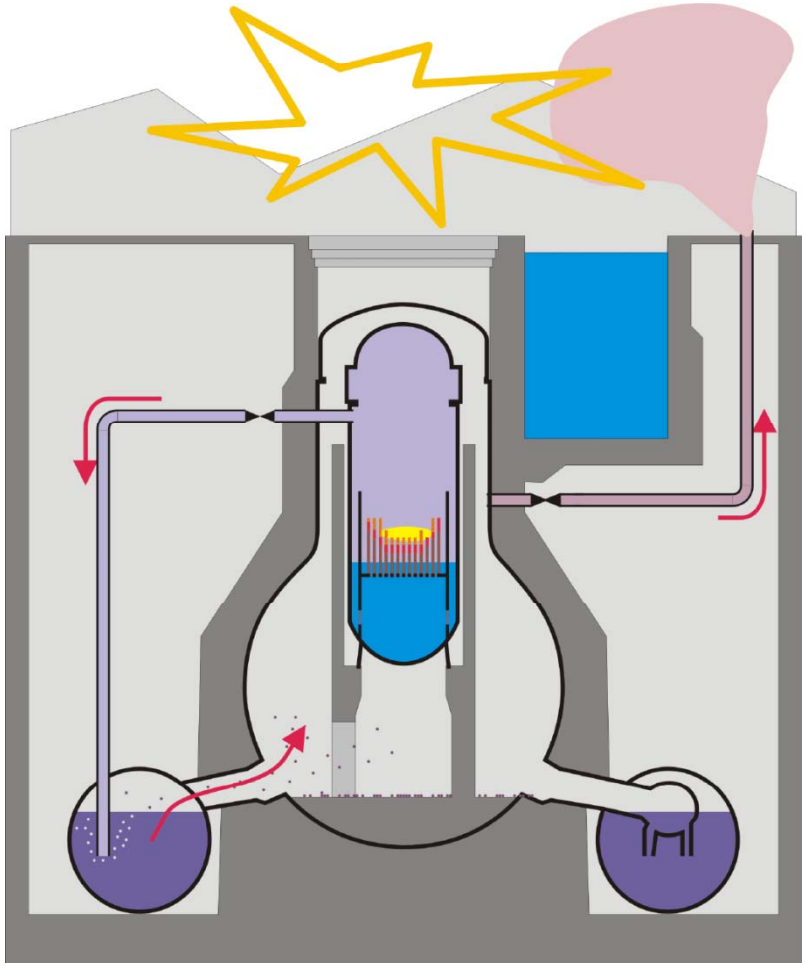
Units 1, 3

12 - 14.3.2011

Hydrogen explosions in units 1, 3

Release of noble gases
Small release of aerosols – Cs, I

Accident – level 5?



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Units 2,3,4,5,6

Accident progressing

3-9. Chronology of Unit 2 after the earthquake (1/2)

● *Unit 2*

11th	● Under operation, Automatic shutdown by the earthquake ● Loss of A/C power ● Loss of water injection function
14th	● Loss of water cooling function ● Unusual increase in PCV pressure
15th	● Sound of explosion ● Possible damage of the suppression chamber
20th	● Injection of about 40 tons of seawater into SFP through fire extinguishing system. ● Injection of seawater to the Spent Fuel Pool (SFP)
21st	● White smoke generated
22nd	● Injection of seawater to the Spent Fuel Pool (SFP)
25th	● Injection of seawater to SFP

3-9. Chronology of Unit 2 after the earthquake (2/2)

● *Unit 2(Continued)*

26th ●Lighting in the Central Control Room was recovered

27th ●Switched to the water injection to the core using a temporary motor-driven pump.

29th ●The Seawater injection to the Spent Fuel Pool using the Fire Pump Truck was switched to the fresh water injection using the temporary motor-driven pump

●In order to prepare for transferring the stagnant water on the basement floor of turbine building to the Condenser, the water in the Condensate Storage Tank is being transferred to the Surge Tank of Suppression Pool Water.

30th ●The injection pump was switched to the Fire Pump Truck. However, because cracks were confirmed in the hose (12:47 and 13:10 March 30th), the injection was suspended. The injection of fresh water resumed at 19:05 March 30th.

31st ●White smoke was confirmed to generate continuously.

●Fresh water is being injected to the spent fuel pool and the RPV

Unit 2

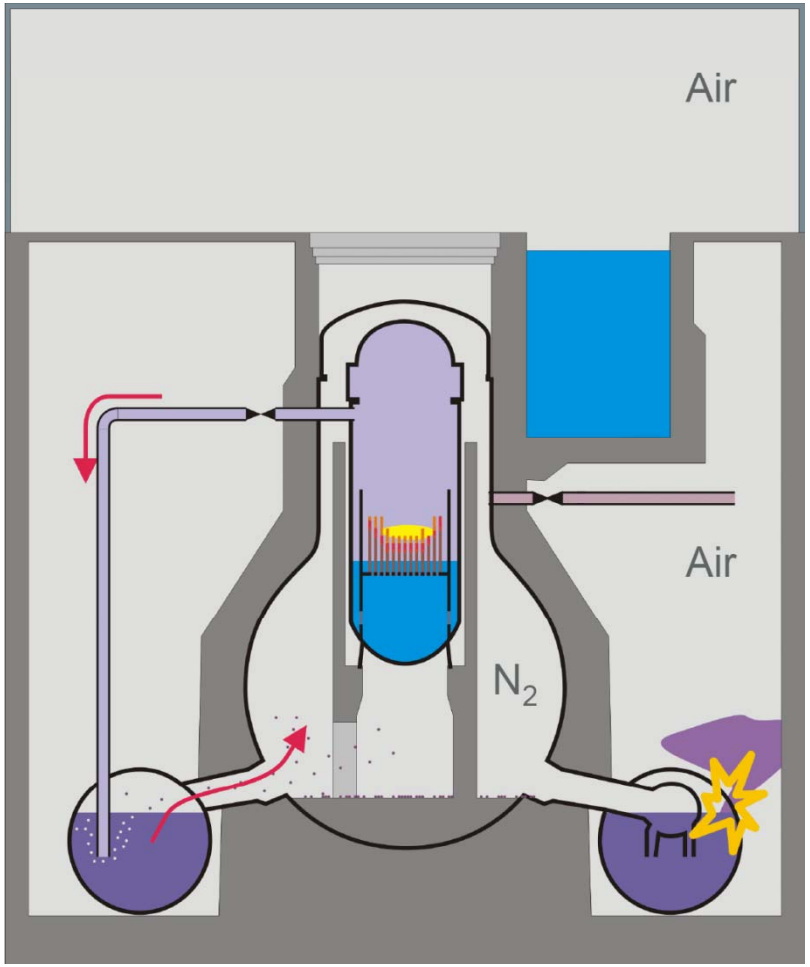
15.3.2011

Explosion i buttom of unit 2
(condensation chamber)
Damage to containment

Release of fission products

High radiation levels
Evacuation of the plant

Accident – level 6-7?



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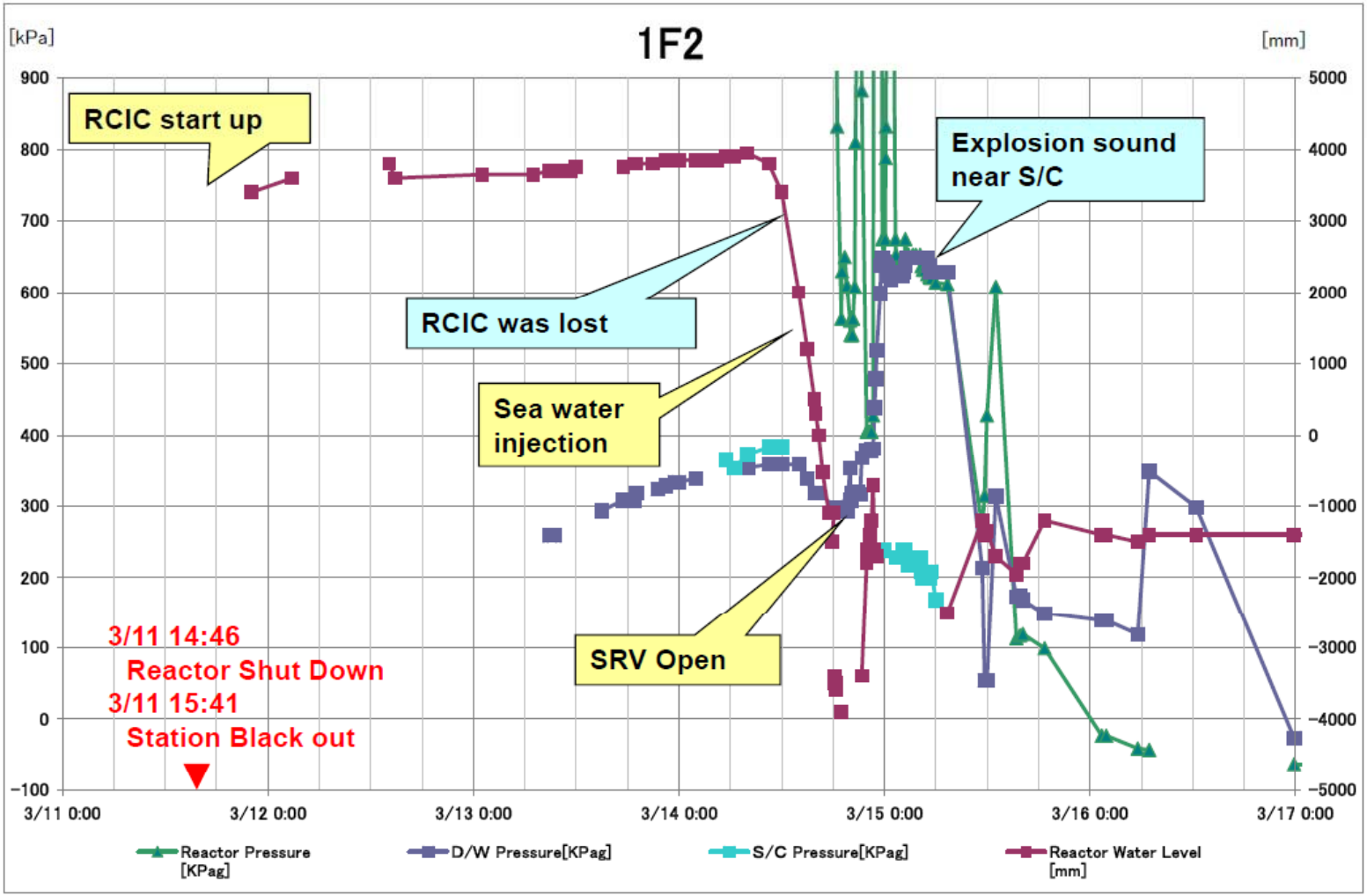
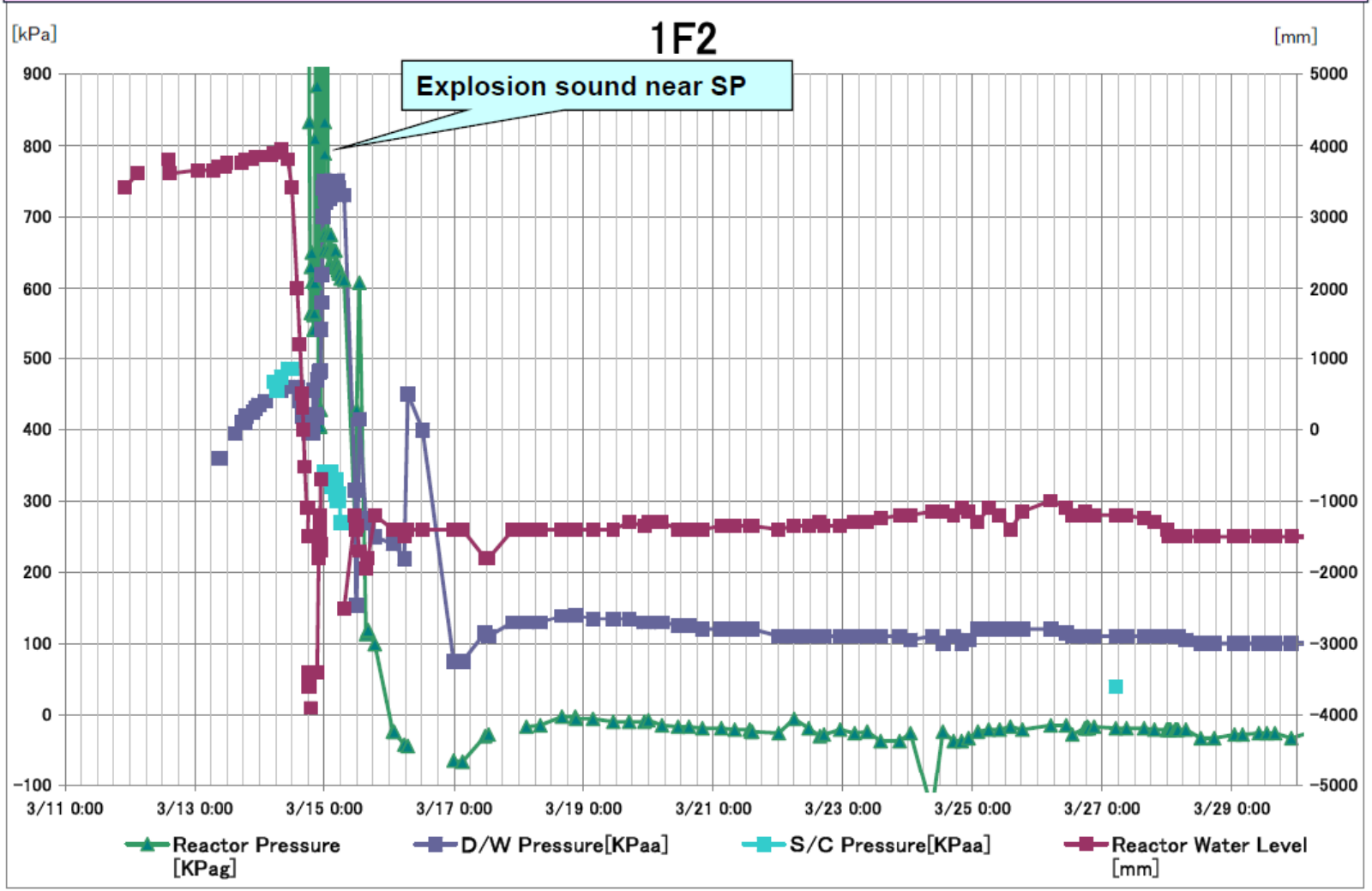
3-10. Trend data of Unit 2 until March 17



3-11. Trend data of Unit 2 until March 30



3-12. Chronology of Unit 3 after the earthquake (1/2)

● *Unit 3*

11th
- ●Under operation, Automatic shutdown by the earthquake
- ● Loss of A/C power

13th
- ● Loss of water injection function
- ● Started to vent

14th
- ●Unusual increase in PCV pressure
- ●Sound of explosion

16th
- ●White smoke generated

17th
- ●Water discharge by the helicopters of Self-Defense Force(4 times)
- ●Water spray from the ground by High pressure water-cannon trucks (Police: once, Self-Defense Force: 5 times)

18th
- ●Water spray from the ground by same trucks (Self-Defense Force: 6 times)

Water spray from the ground by US water-cannon trucks (US armed force:1 time)

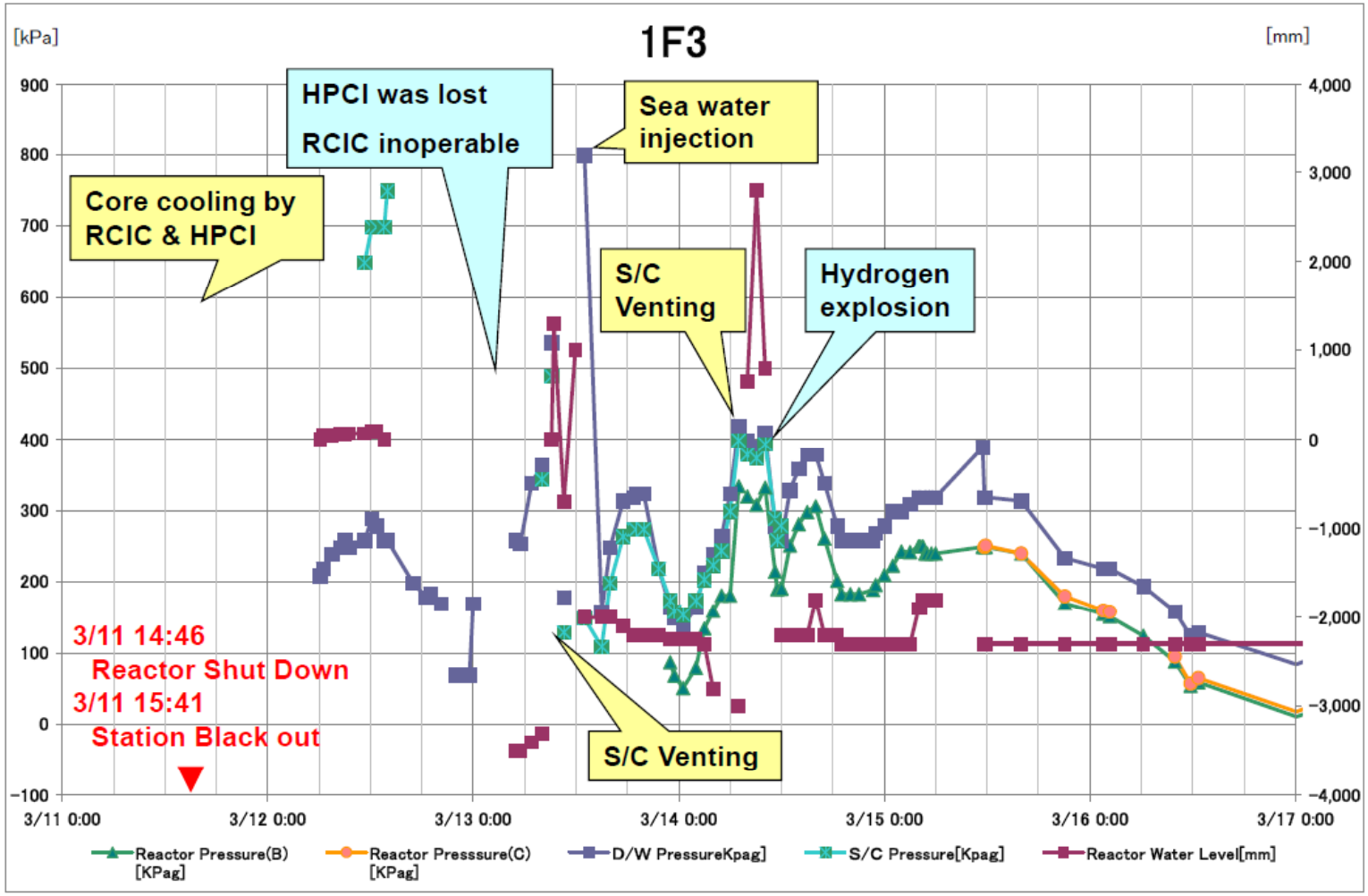
19th
- ●Water spray from the ground by High pressure water-cannon trucks by Hyper Rescue Unit of Tokyo Fire Department.

3-12. Chronology of Unit 3 after the earthquake (2/2)

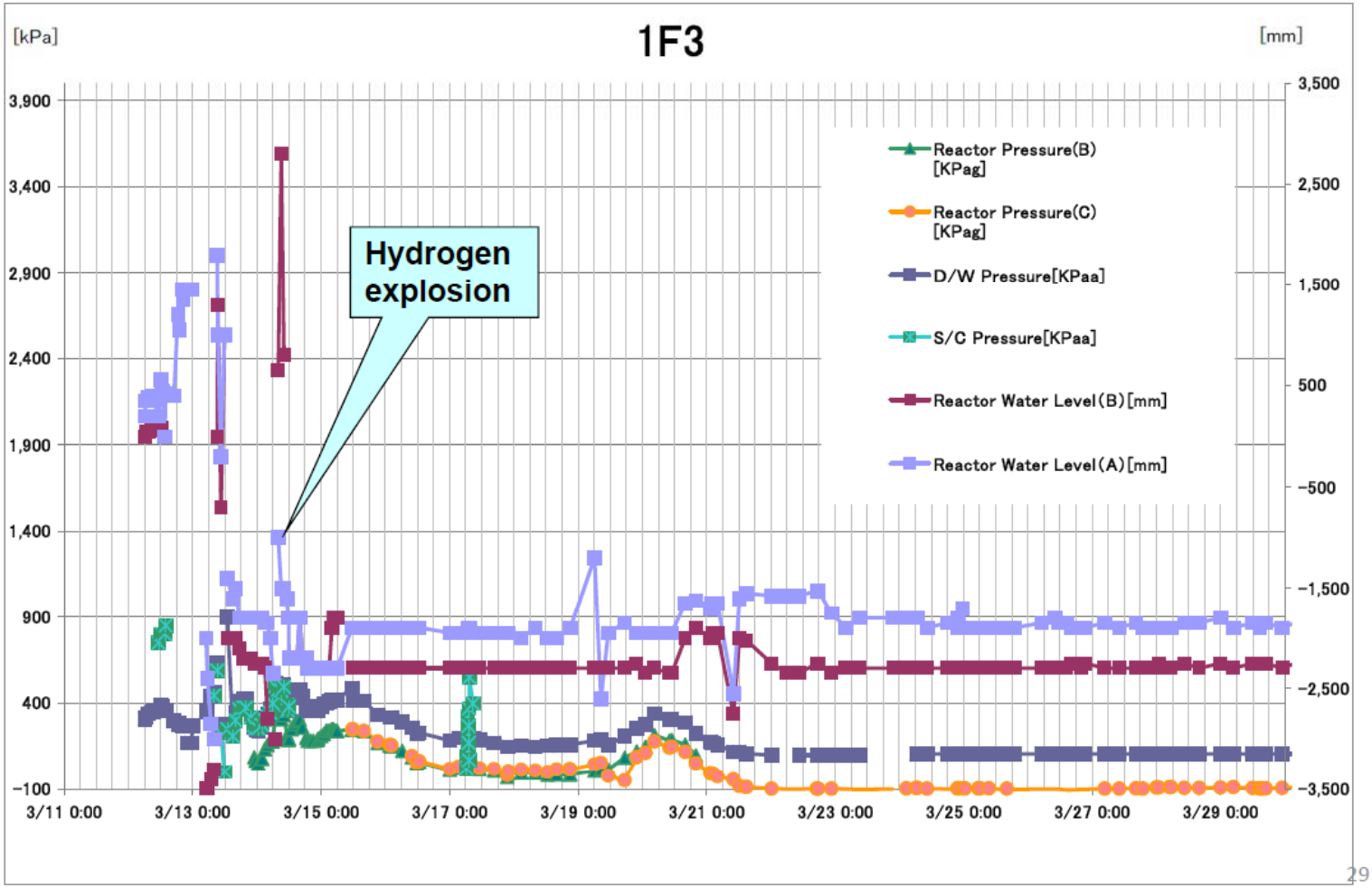
●*Unit 3(Continued)*

20th	●Sprayed by Hyper Rescue Unit of Tokyo Fire Department
22nd	●Lighting in the Central Control Room was recovered.
23rd	●Injection of seawater to the SFP
24th	●Injection of seawater to the SFP
25th	●Water spray (Emergency fire support team ●Started fresh water injection
27th	●Water spray by Concrete Pump Truck
28th	●Switched to the water injection to the core using a temporary motor-driven pump ●In order to prepare for transfer the stagnant water on the basement floor of turbine building to the Condenser, the water in the Condensate Storage Tank is being transferred to the Surge Tank of Suppression Pool Water
29th	●Started to spray freshwater by Concrete Pump Truck
31st	●White smoke was confirmed to generate continuously ●Fresh water is being injected to the spent fuel pool and the RPV

3-13. Trend data of Unit 3 until March 17



3-14. Trend data of Unit 3 until March 30



29

3-16. Chronology of Unit 4 after the earthquake

Unit 4

14th	●Water temperature in the Spent Fuel Pool, 84℃
15th	●Damage of wall in the 4th floor confirmed ●Fire occurred in the 3rd floor (12:25 extinguished)
16th	●Fire occurred. TEPCO couldn't confirm any fire on the ground.
20th	●Water spray over the spent fuel pool by Self Defense Force
21st	●Water spray over the spent fuel pool by Self Defense Force
22nd-24th	●Water spray (Concrete Pump Track (3 times)
25th	●Injection of seawater to SFP via the Fuel Pool Cooling Line (FPC) ●Water spray (Concrete Pump Truck)
27th	●Water spray (Concrete Pump Truck)
29th	●Lighting in the Central Control Room was recovered.
3oth	●White smoke was confirmed to generate continuously. ●Spray of fresh water (Around 140t) over the Spent Fuel Pool using Concrete Pump Truck (50t/h) was carried out. ●Fresh water is being injected to the spent fuel pool

31

3-17. Chronology of Unit 5 & 6 after the earthquake

● *Unit 5&6*

20th	●Unit 5 under cold shutdown (Water temperature of reactor water is less than 100℃) ●Unit 6 under cold shutdown (Water temperature of reactor water is less than 100℃)
21st	●Water spray over the Common Spent Fuel Pool started
22nd	●Recovering power supply of unit 5 and 6 is completed.
24th	●The power was started to be supplied. Cooling also started
30th	●Bach up power of Unit 6 is in working condition and external power was supplied to Unit 5 as of March 30th

Spent fuel pools

15-16.3.2011

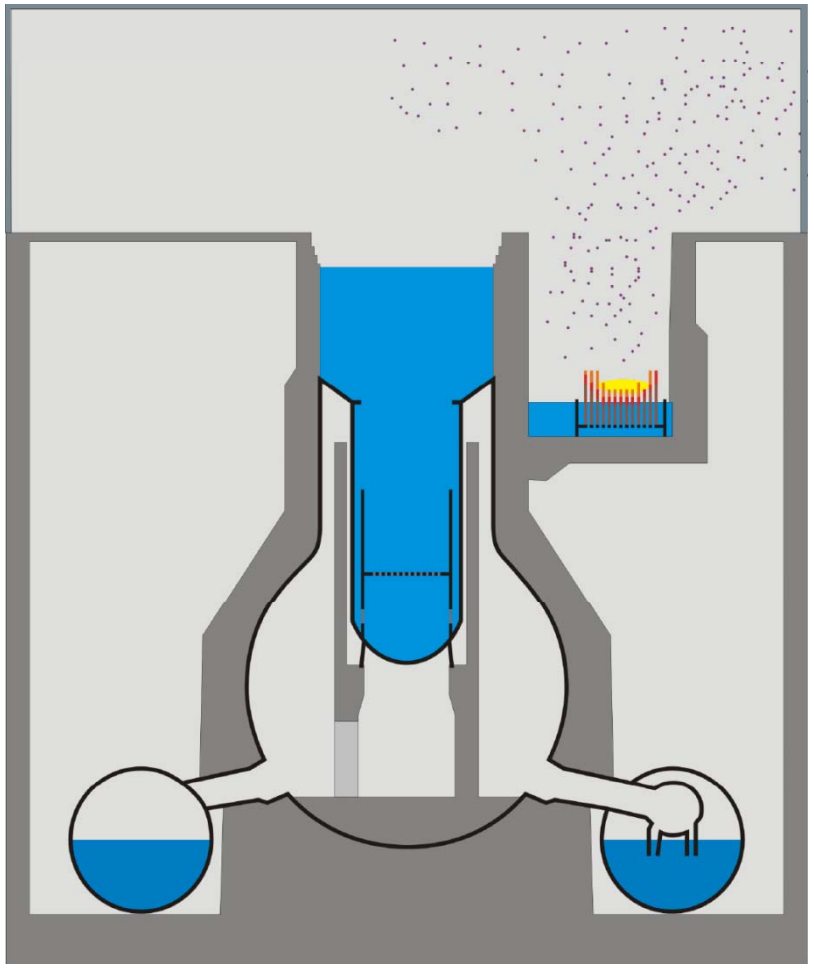
Spent fuel pools outside reactor containment

No external cooling
Leakage of pools?

Passive cooling:
Unit 4 ~ days
Units 1-3,5,6 ~ weeks

Meltdown of spent fuel?
Large releases?

Accident – level 7?



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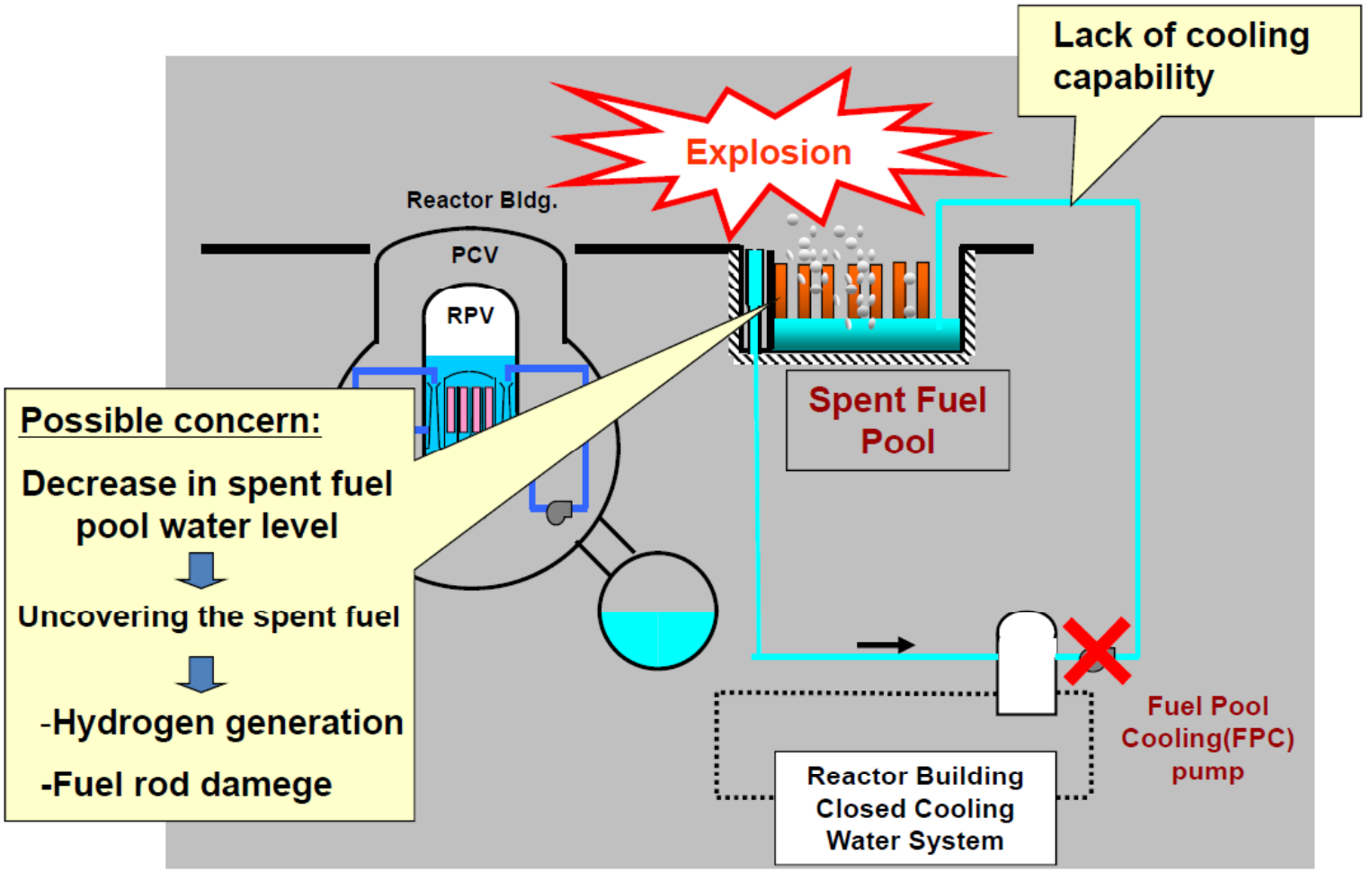
Report concerning incidents at spent fuel pools in the Fukushima Dai-ichi NPS

Photo: Water spray into the SFP in Unit 4 using concrete pump truck

4-1. Possible concerns about Spent Fuel Pool



4-2. Status of the Fuel as of March 11, 2011

Unit	1	2	3	4	5	6
Number of Fuel Assembly in the Core	400	548	548	-	548	764
Number of Spent Fuel Assembly in the Spent Fuel Pool	292	587	514	1,331	946	876
Number of New Fuel Assembly in the Spent Fuel Pool	100	28	52	204	48	64
Water Volume (m^3)	1,020	1,425	1,425	1,425	1,425	1,497

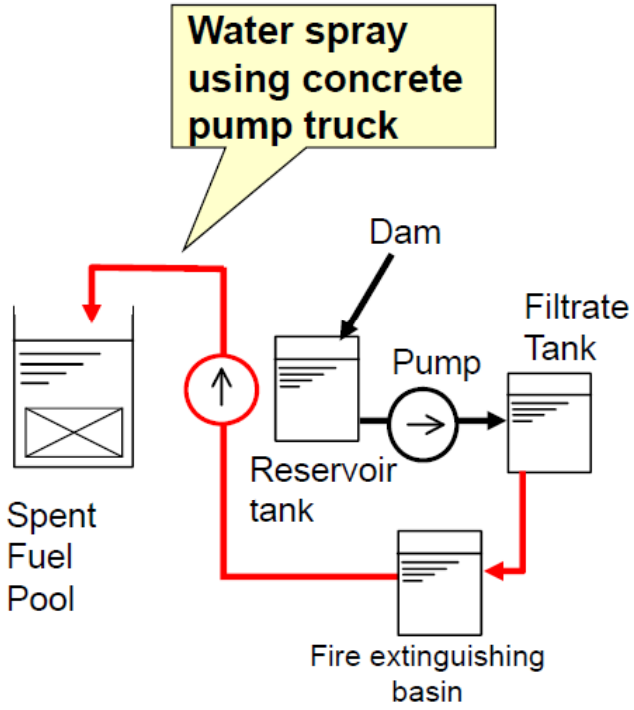
Condition of the fuel in the Spent Fuel Pool

Unit 1	Unit 2	Unit 3	Unit 4
-Most recent shut down was on Sep.27,2010	- Most recent shut down was on Nov.18,2010	- Most recent shut down was on Sep.23,2010	-Most recent shut down was on Nov.29,2010 -All fuel assembly was removed from the core and located in the pool due to the core shroud replacement

4-3. Measures taken to cool the Spent Fuel Pool (1/4)

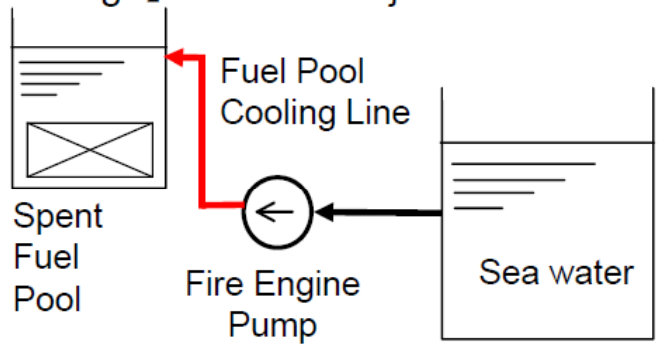
Unit 1

Fresh water injection

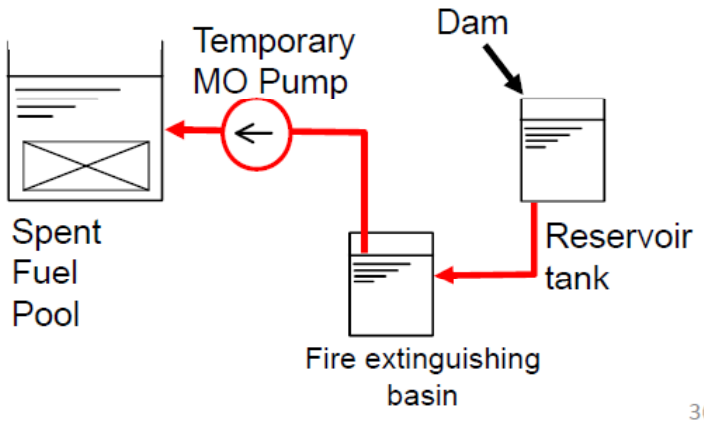


Unit 2

【1st Stage】Sea water injection



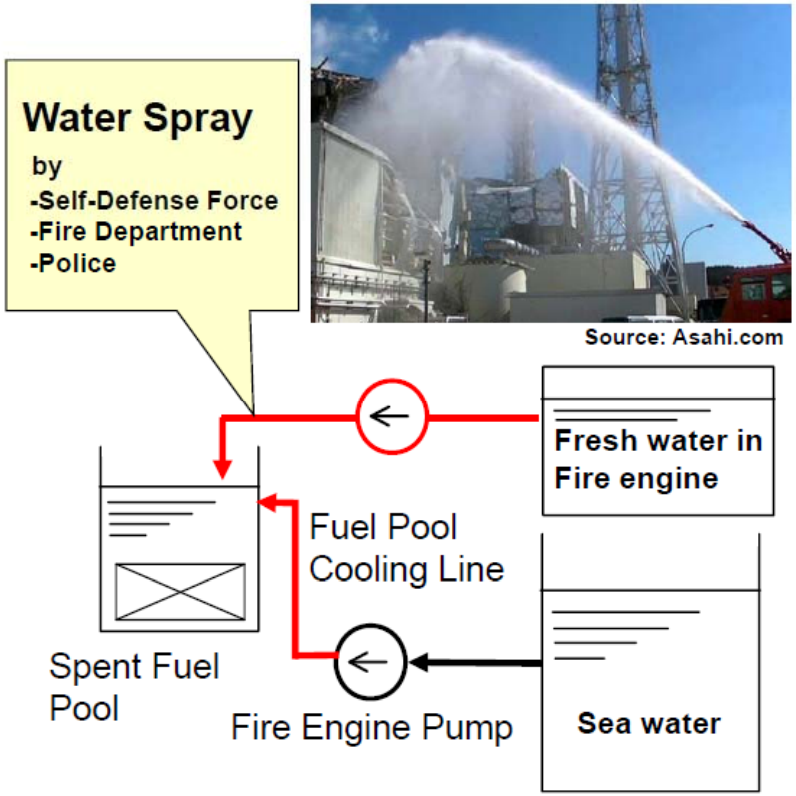
【2nd Stage】Fresh water injection



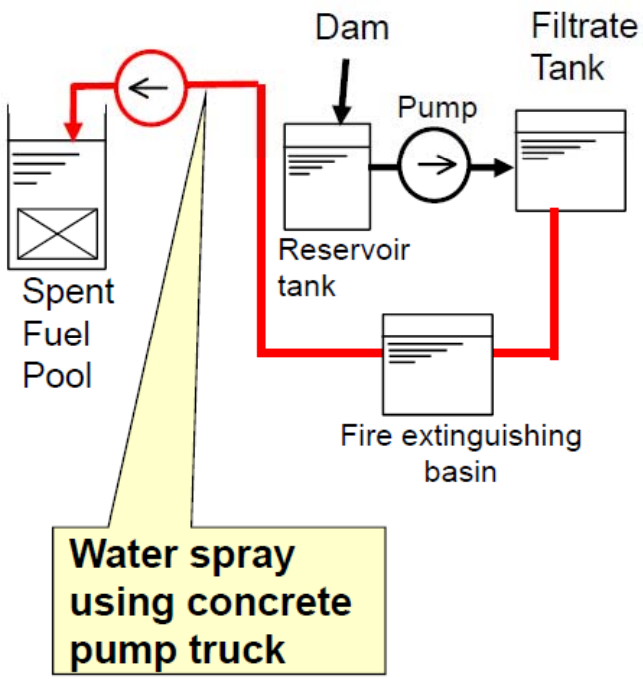
4-3. Measures taken to cool the Spent Fuel Pool (2/4)

Unit 3

【1st Stage】Sea water injection



【2nd Stage】Fresh water injection



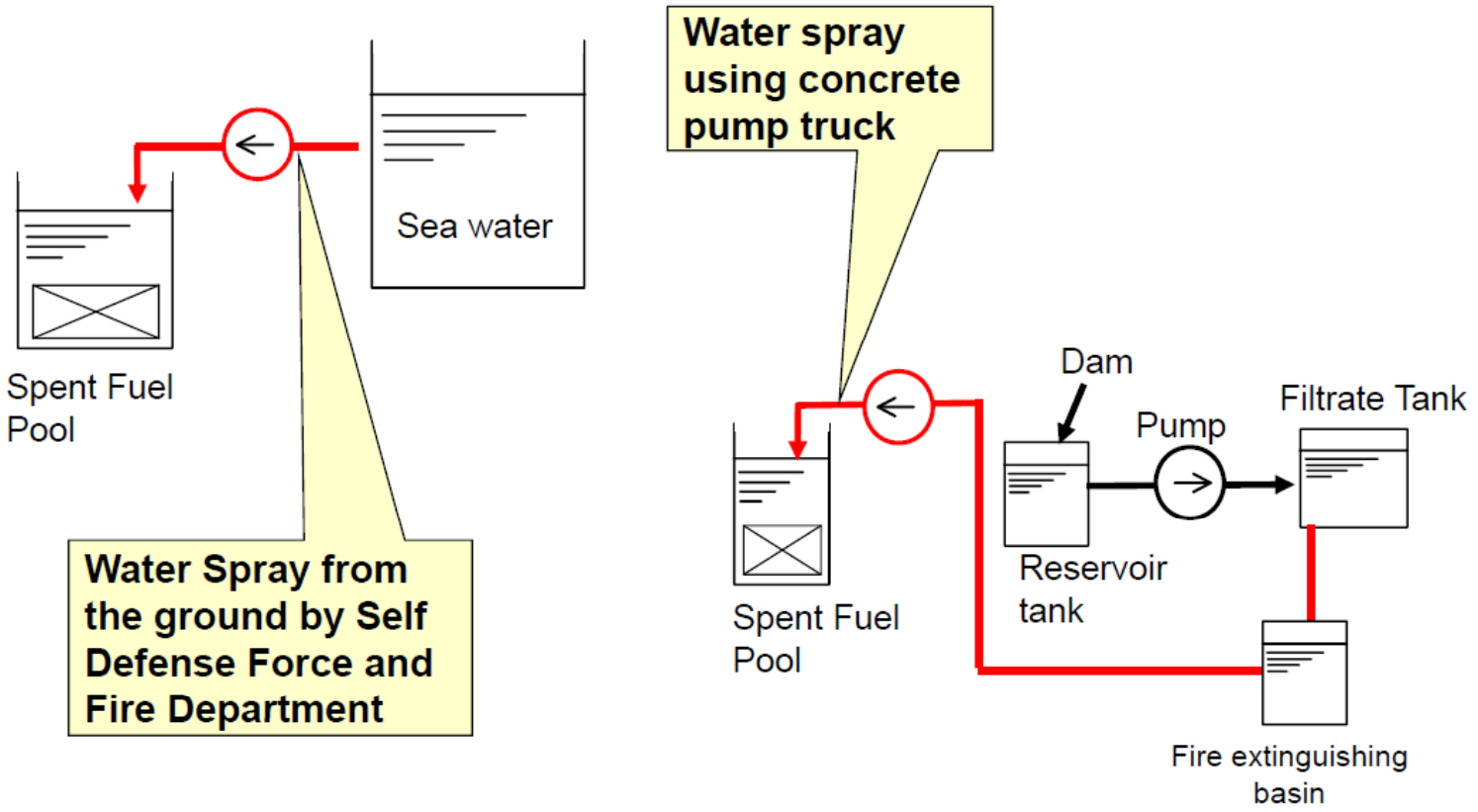
*** Sea water discharge by helicopters of the Self Defense Force**

4-3. Measures taken to cool the Spent Fuel Pool (3/4)

Unit 4

【1st Stage】Sea water injection

【2nd Stage】Fresh water injection



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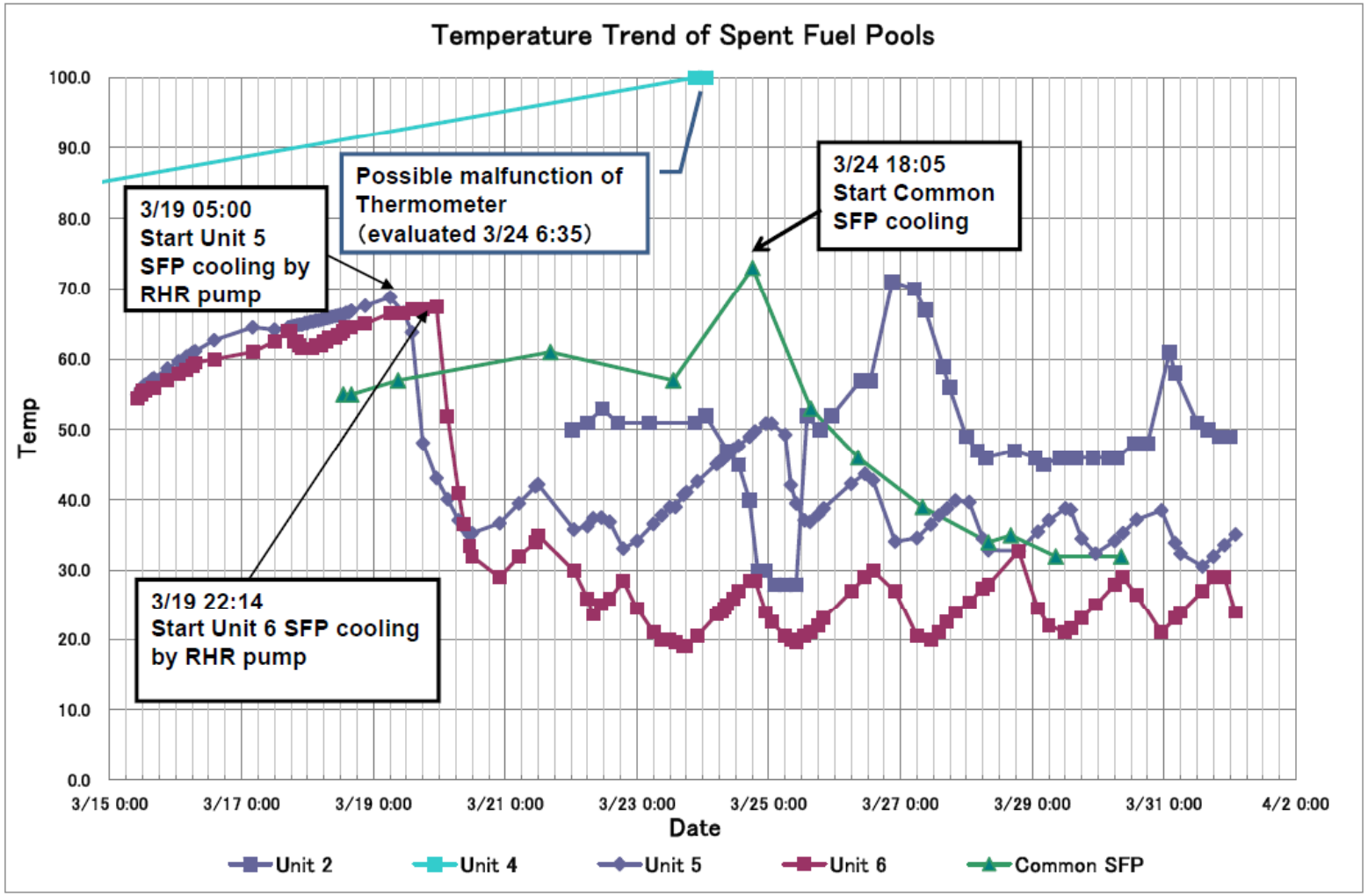
4-3. Measures taken to cool the Spent Fuel Pool (4/4)



Current status – 27.4.2011

Partial meltdown of fuel in reactors 1-3

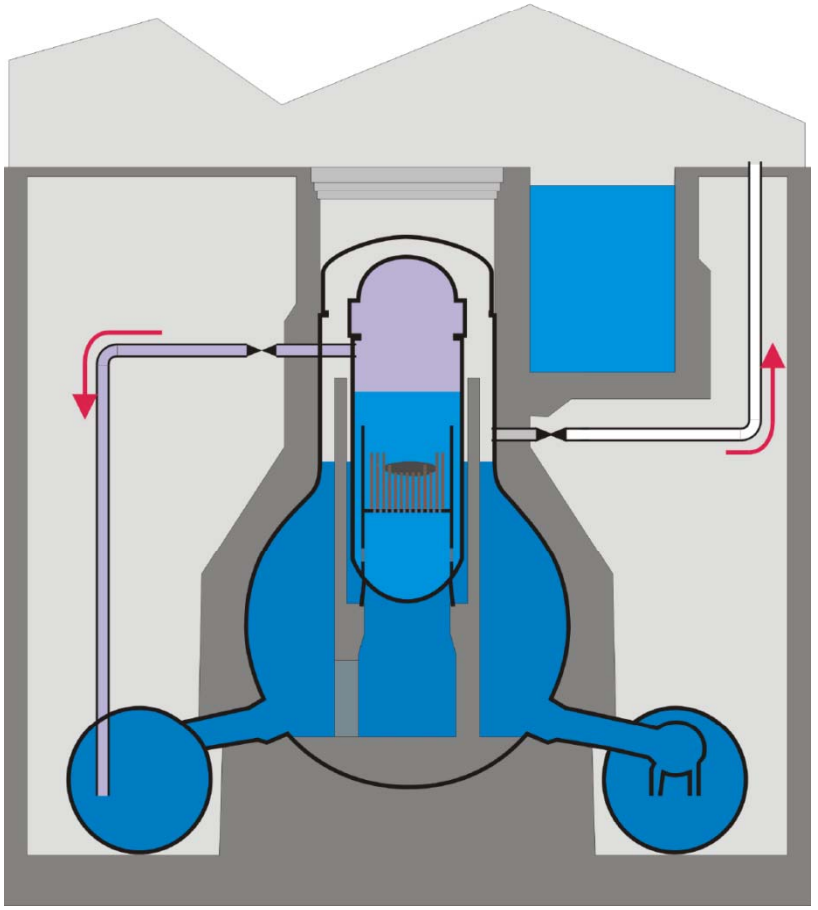
Damage to containment in unit 2

Damage to spent fuel in unit 4

Feed of water in reactor pressure vessels, pools

External power to units 1-4 but no external cooling

Accident – level 7?



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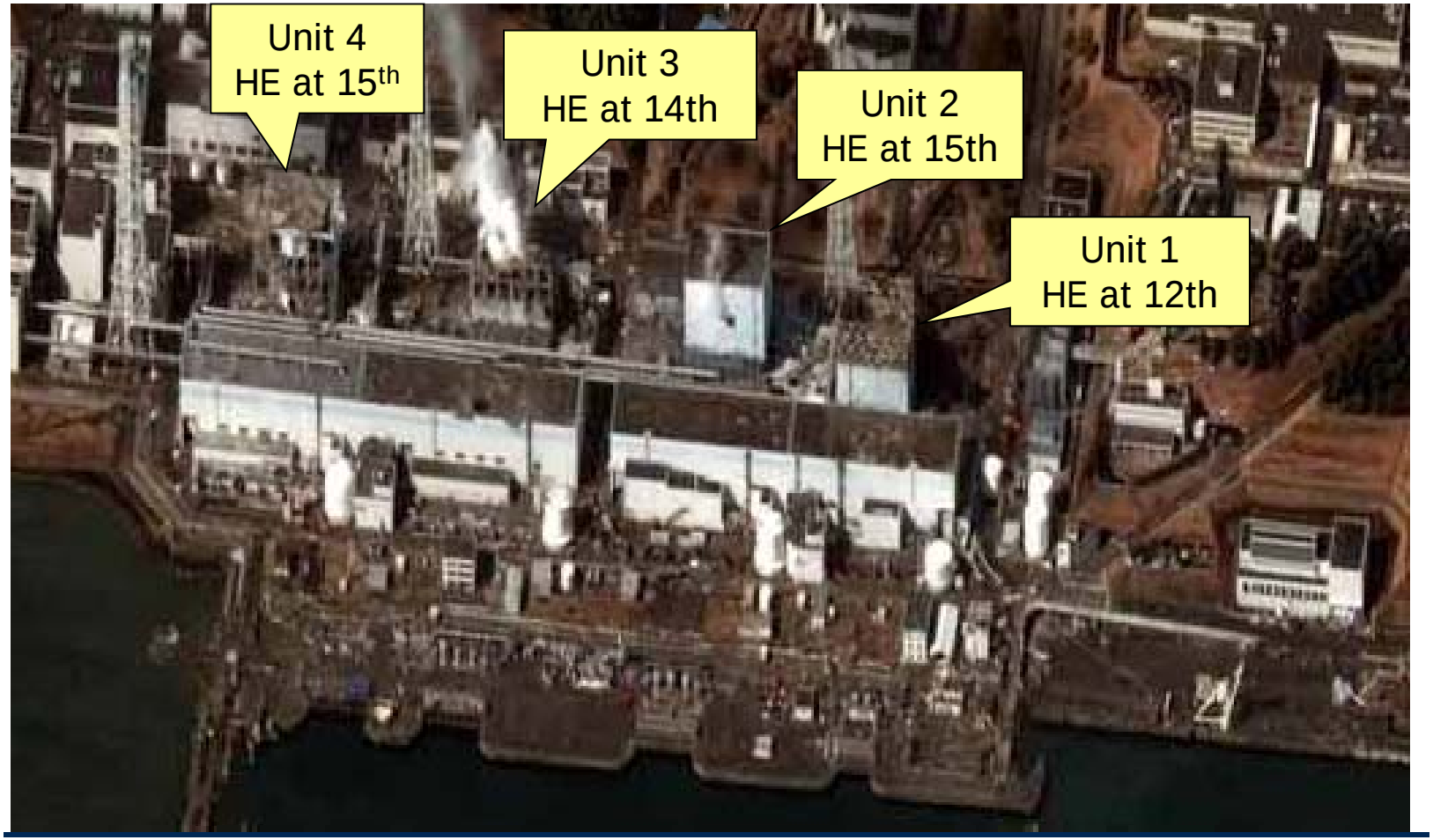
DTU

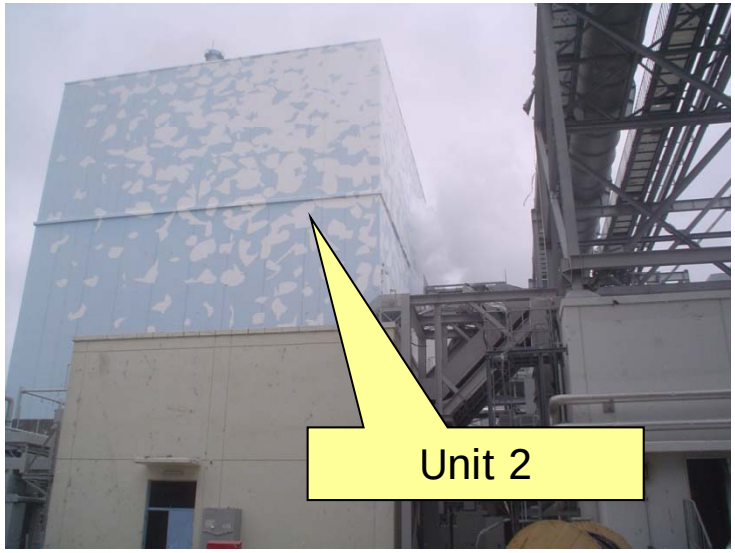
View of Units 1, 2, 3, 4 After Explosions

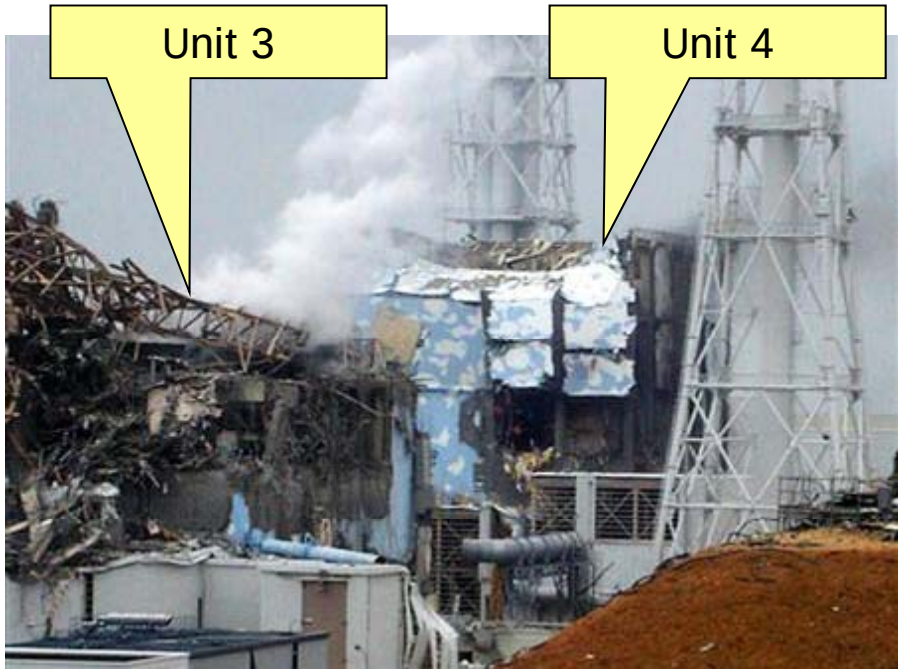


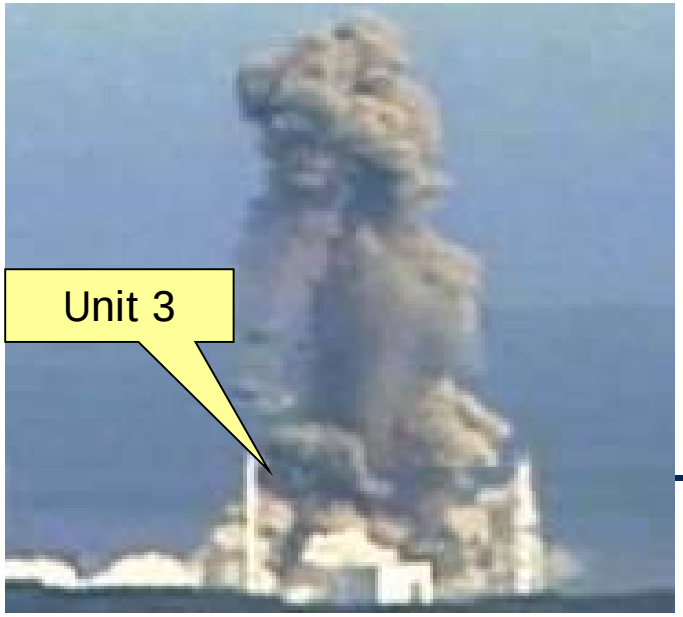
Hydrogen explosion at Unit 1 & 3

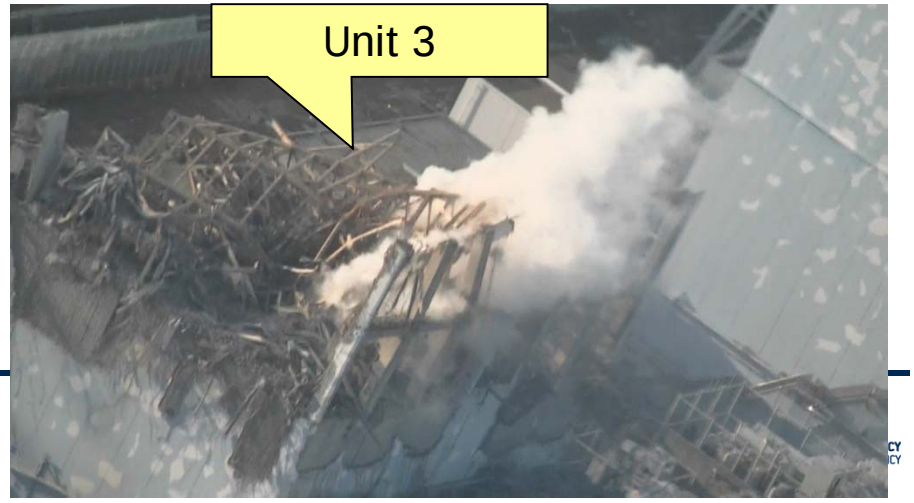
DEMA DANISH EMERGENCY MANAGEMENT AGENCY

Accident Progression at Units 2, 3, 4

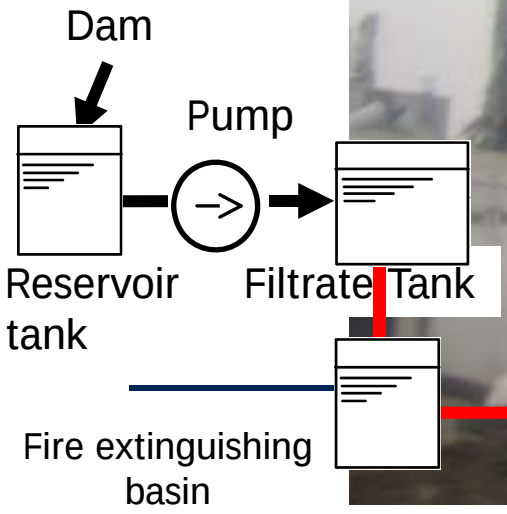








Water spray into the SFP of Unit 4 using concrete pump truck



Current status – 27.4.2011

Partial meltdown of fuel in reactors 1-3

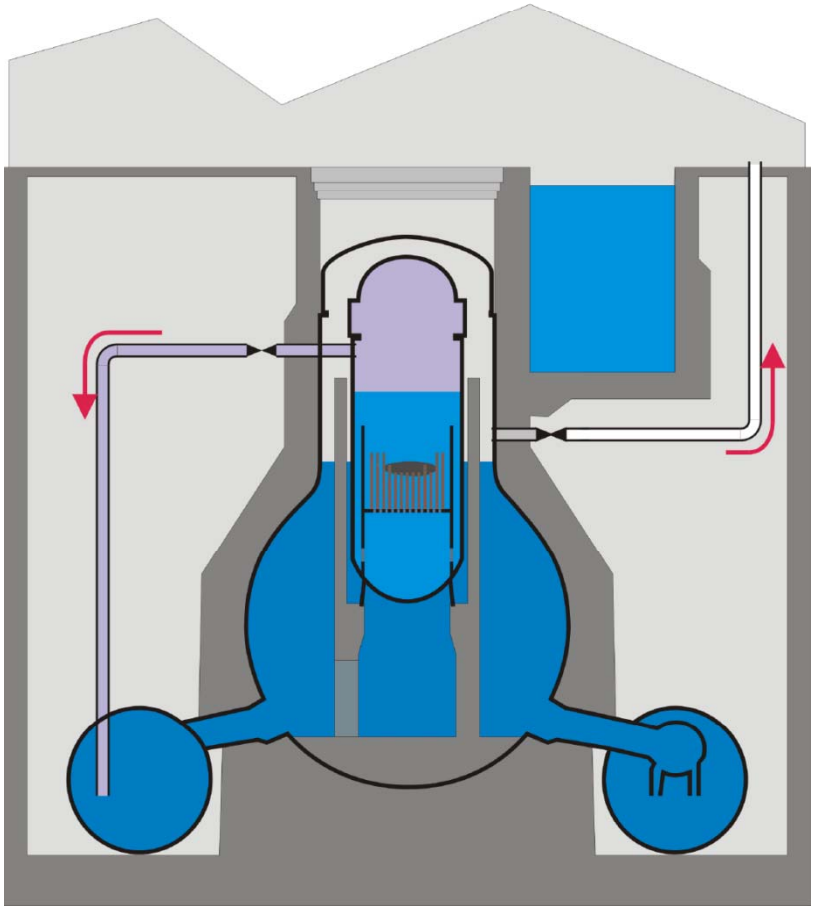
Damage to containment in unit 2

Damage to spent fuel in unit 4

Feed of water in reactor pressure vessels, pools

External power to units 1-4 but no external cooling

Accident – level 7?



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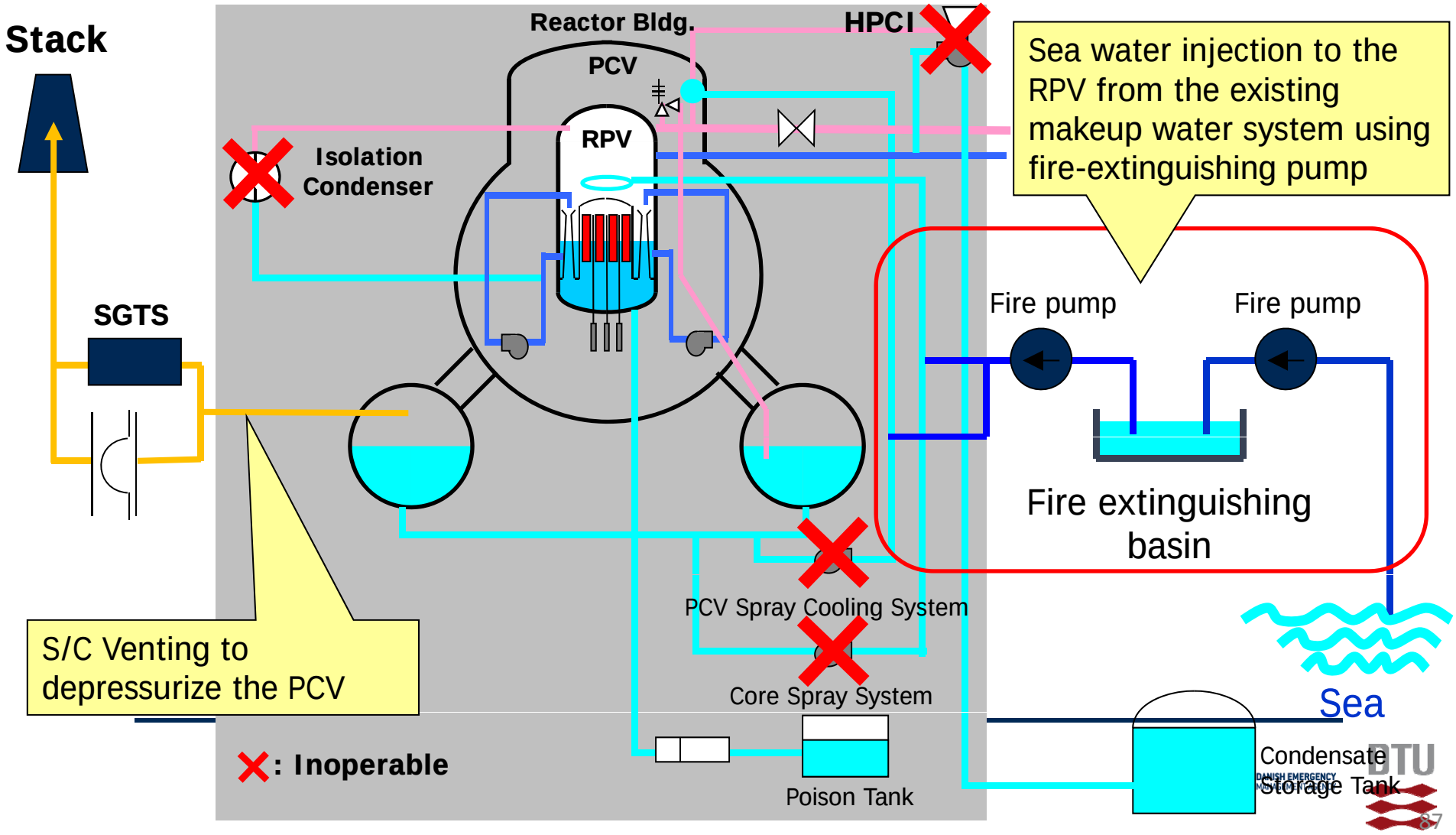
Countermeasures at Unit 1

- Sea water injection using fire water pump - S/C Venting to depressurize the PCV



Status of nuclear power plants in Fukushima as of 12:00, May 17th (Estima

Power Station	Fukushima Dai-ichi Nuclear Power Statio		
Unit	1	2	3
Electric / Thermal Power output (MW)	460 / 1380	784 / 2381	784 / 2381
Type of Reactor	BWR-3	BWR-4	BWR-4
Operation Status at the earthquake occurred	In Service -> Shutdown	In Service -> Shutdown	In Service -> Shutdown
Fuel assemblies loaded in Core	400	548	548
Core and Fuel Integrity (Loaded fuel assemblies)	Damaged (most part*4)	Damaged (35%*1)	Damaged (30%*1)
Reactor Pressure Vessel structural integrity	Damage and Leakage estimated	Unknown	Unknown
Containment Vessel structural integrity	Damage and Leakage estimated	Damage and Leakage Suspected	Not damaged (estimation)
Core cooling requiring AC power 1 (Large volumetric freshwater injection)	Not Functional	Not Functional	Not Functional
Core cooling requiring AC power 2 (Cooling through Heat Exchangers)	Not Functional	Not Functional	Not Functional
Building Integrity	Severely Damaged (Hydrogen Explosion)	Partly opened	Severely Damaged (Hydrogen Explosion)
Water Level of the Rector Pressure Vessel	Lower than the bottom of fuels	Fuel exposed partially or fully	Fuel exposed partially or fully
Pressure / Temperature of the Reactor Pressure Vessel	Gradually increasing / Decreased a little after increasing over 400℃ on Mar. 24th	Unknown / Stable	Unknown / Gradually increasing
Containment Vessel Pressure	Decreased a little after increasing up to 0.4Mpa on Mar. 24th	Stable	Stable
Water injection to core (Accident Management)	Continuing (Switch from seawater to freshwater)	Continuing (Switch from seawater to freshwater)	Continuing (Switch from seawater to freshwater)
Water injection to Containment Vessel (AM)	Feed water to fill up the CV (started 4/27)	Feed water to fill up the CV (planned)	Feed water to fill up the CV (planned)
Containment Venting (AM)	Temporally stopped	Temporally stopped	Temporally stopped
Fuel assemblies stored in Spent Fuel Pool	292	587	514
Fuel Integrity in the spent fuel pool	Unknown	Unknown	Damage Suspected
Cooling of the spent fuel pool	Water spray continues (freshwater)	water injection continues (Switch from seawater to freshwater)	Water spray and injection continues (Switch from seawater to freshwater)
Main Control Room Habitability & Operability	Poor due to loss of AC power (Lighting and parmaeter monitoring restored in the control room at Unit 1 and 3 on Mar. 24th, a		

Beredskab

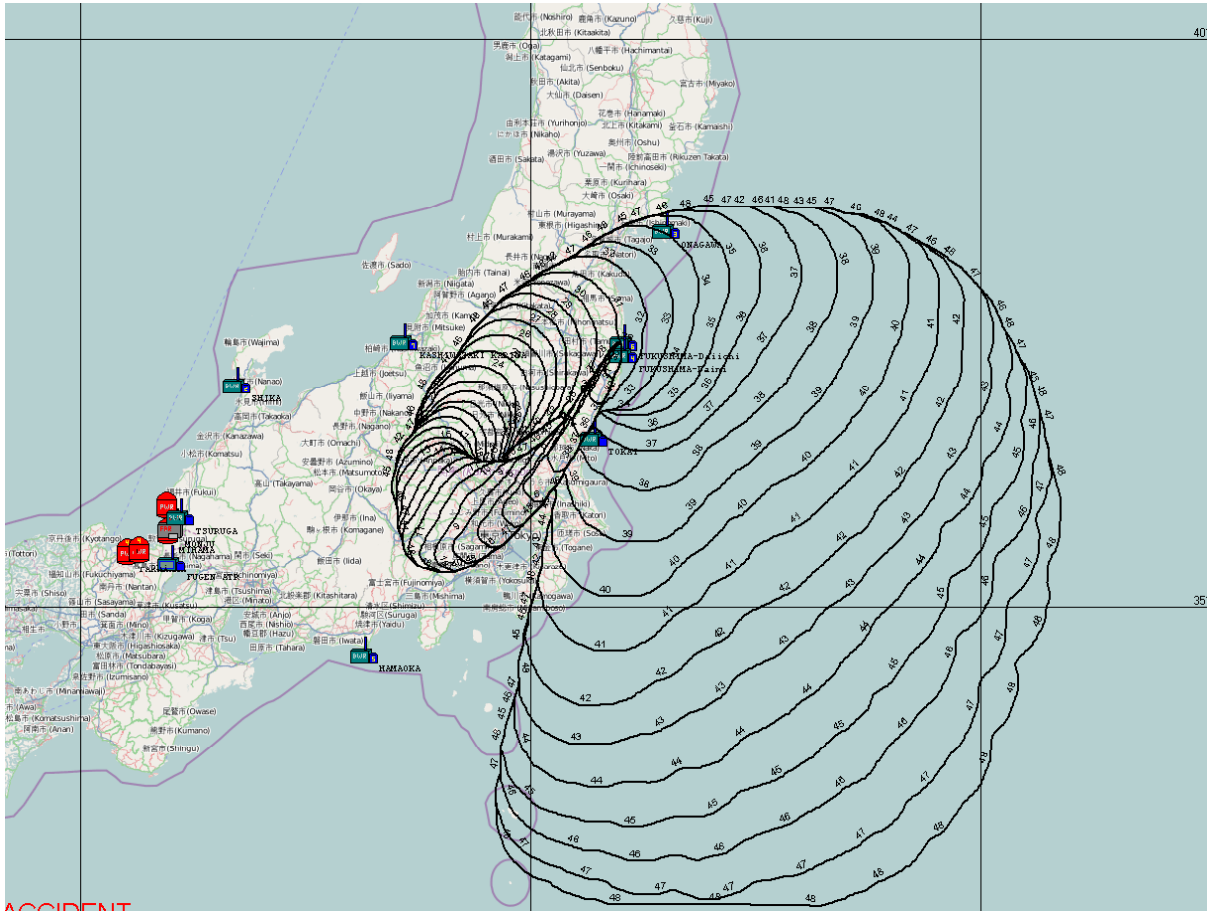
- 16 marts nye rejsevejledninger

Pressebetjening

“Customers”

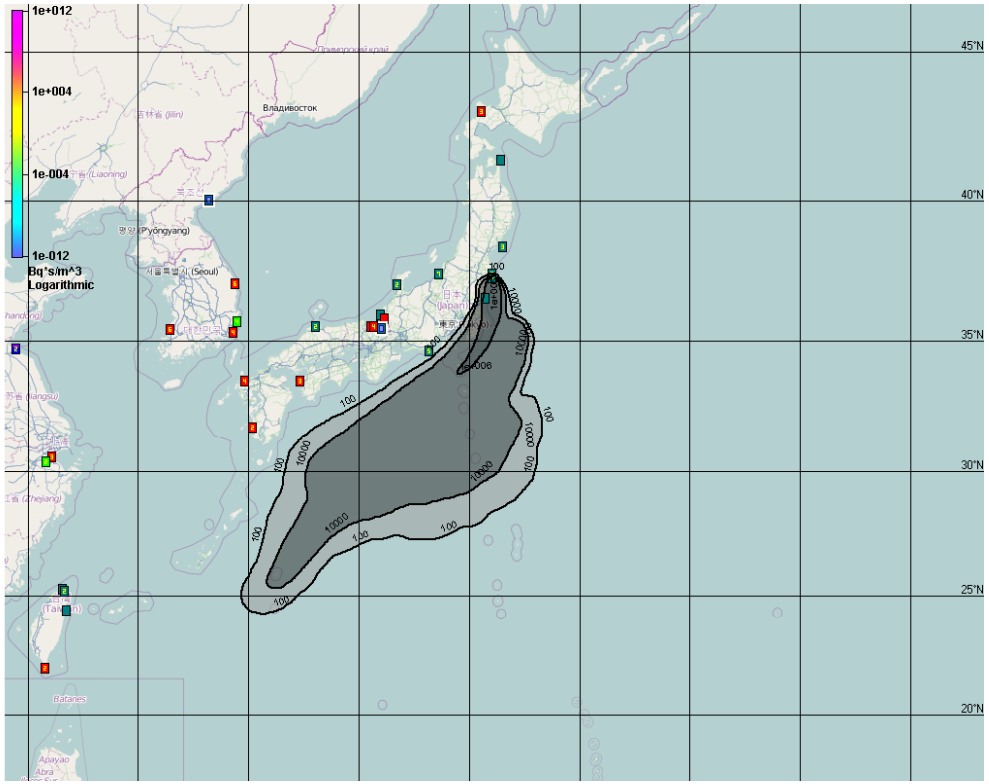
- Danish Embassy
- Maersk, Torn etc

Published 4 times pr day.



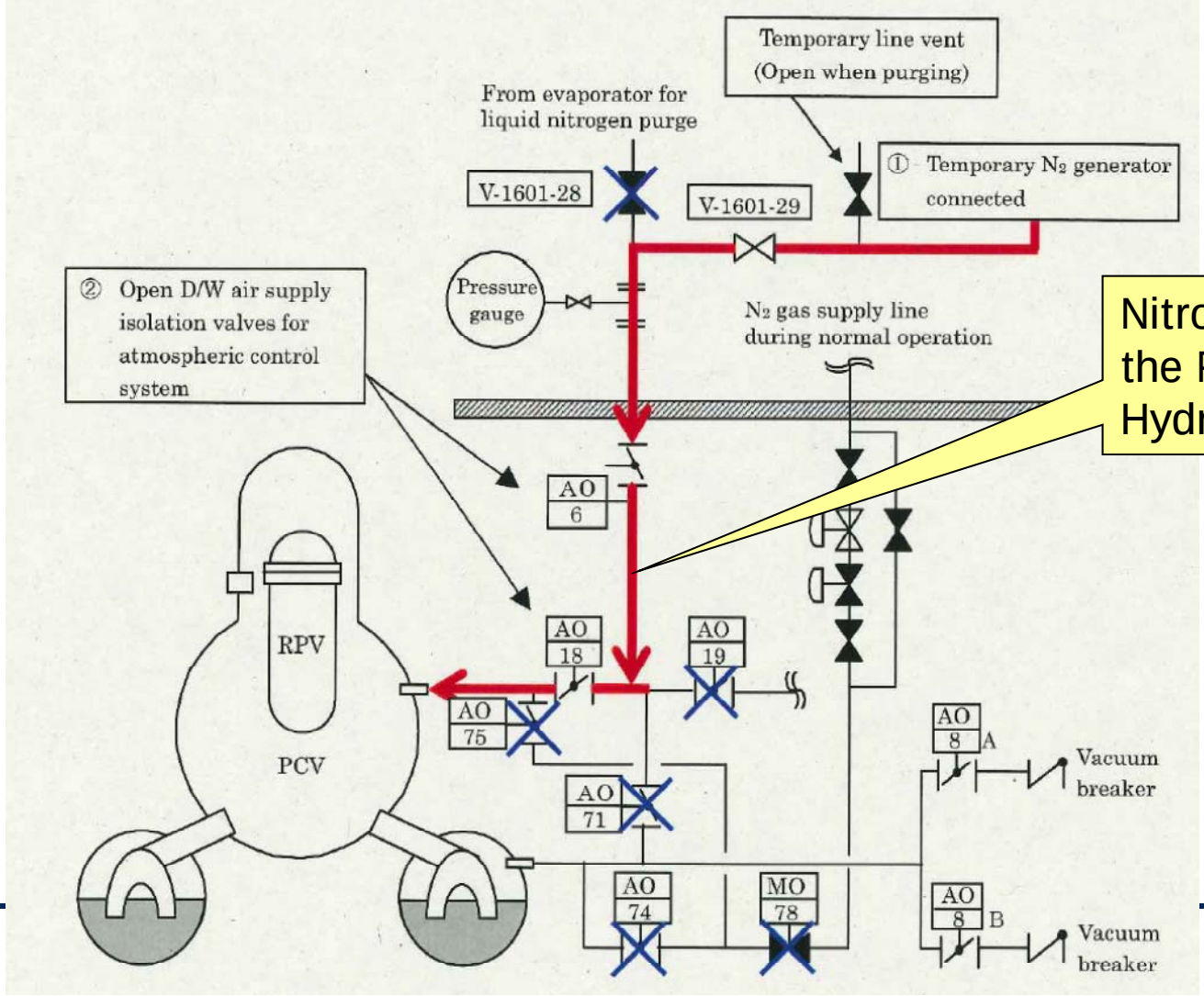
DEMA
Ja_Fukushima_20110403_1000_ECMWF-hr

Air Concentration, Time Integrated
Situation at GMT **04:00:00 04/05/11** for nuclide **Xe-135**
Prognosis ran from GMT **13:00:00 04/03/11** to GMT **07:00:00 04/08/11**



Countermeasures at Unit 1

- *Nitrogen injection to the PCV (since April 6)*

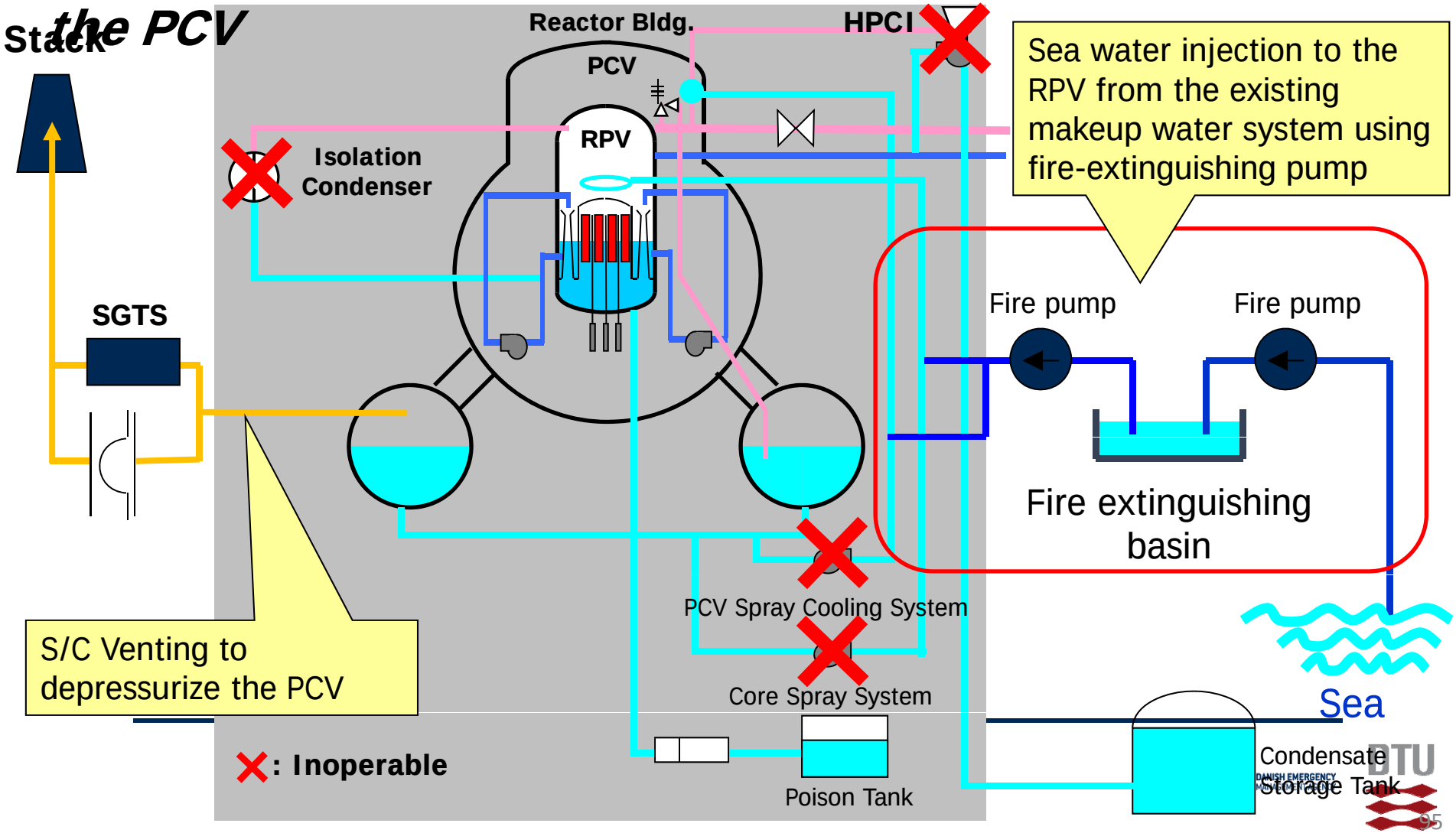


Nitrogen injection to the PCV to prevent Hydrogen explosion

Source: TEPCO

Countermeasures at Unit 1

- Sea water injection using fire water pump - S/C Venting to depressurize the PCV



INES

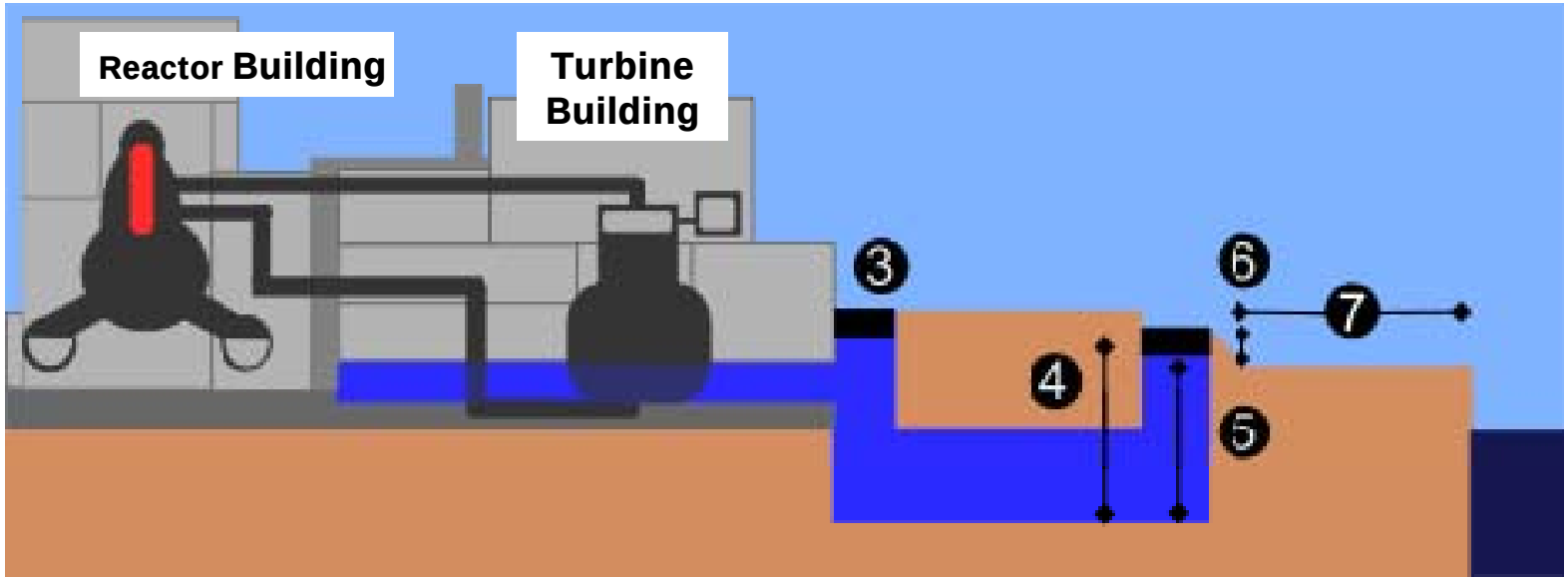
- INES 3 (“Defense in Depth”)
- INES 4 (12 March) “Radiological Barriers and Control”
- INES 5 (18 March)
- INES 7 (Release)

Contamination

Water leakage in trenches

- Highly radioactive water was found in trenches at Units 1, 2 and 3

The Units 2 and 3 trenches were 1 m below the level at which they would overflow into the sea. On the other hand, the unit 1 trench was 10 cm from overflowing. (As of March. 30th)



Side view of the Fukushima trenches and tunnels (*Source: Wikipedia)*

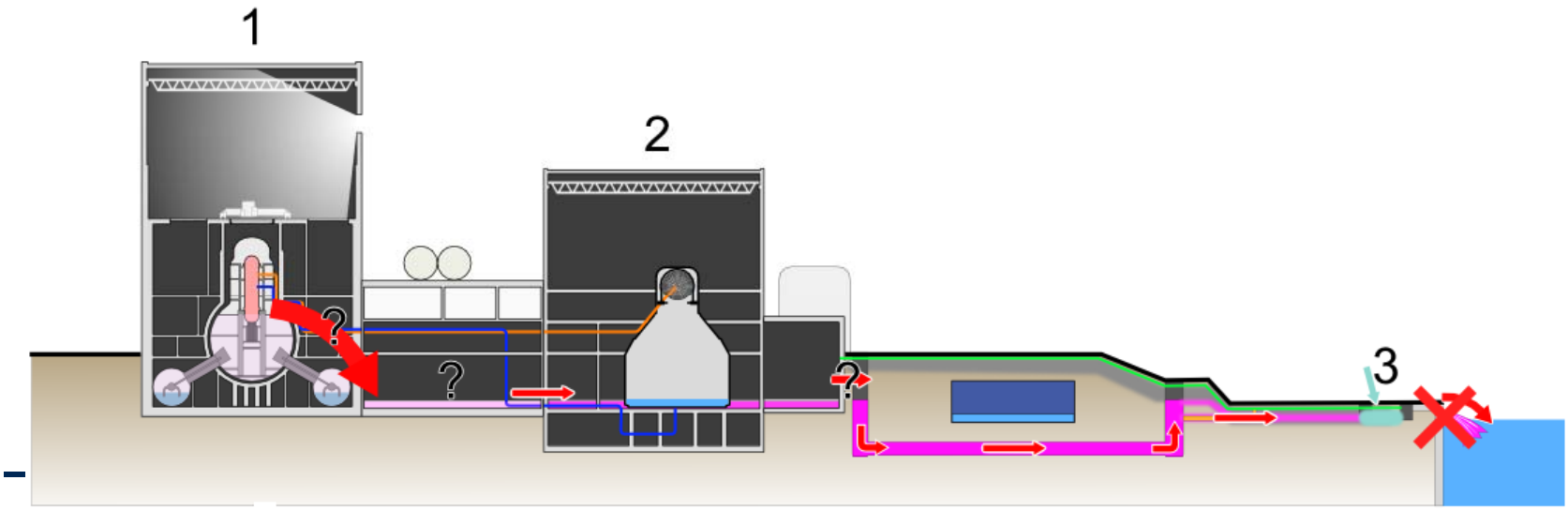
Countermeasures against water leakage to the sea

- Concrete was poured into the pit. (April 2nd)

- The upper part of the Power Cable Trench was crushed and 20 bags of sawdust (3 kg/bag), 80 bags of high polymer absorbent (100 g/bag) and 3 bags of cutting-processed newspaper (Large garbage bag) were put inside. (April 3rd)

- Drilled a hole into the pit and injected water glass (sodium silicate) into the pit. (April 5th)

- On April 6, the outflow was confirmed stopped.



Leakage route of highly radioactive water through a gravel layer.
1: Reactor building, 2: Turbine building, 3: Injection of Sodium Silicate (*Source: Wikipedia)*

DEMA DANISH EMERGENCY MANAGEMENT AGENCY

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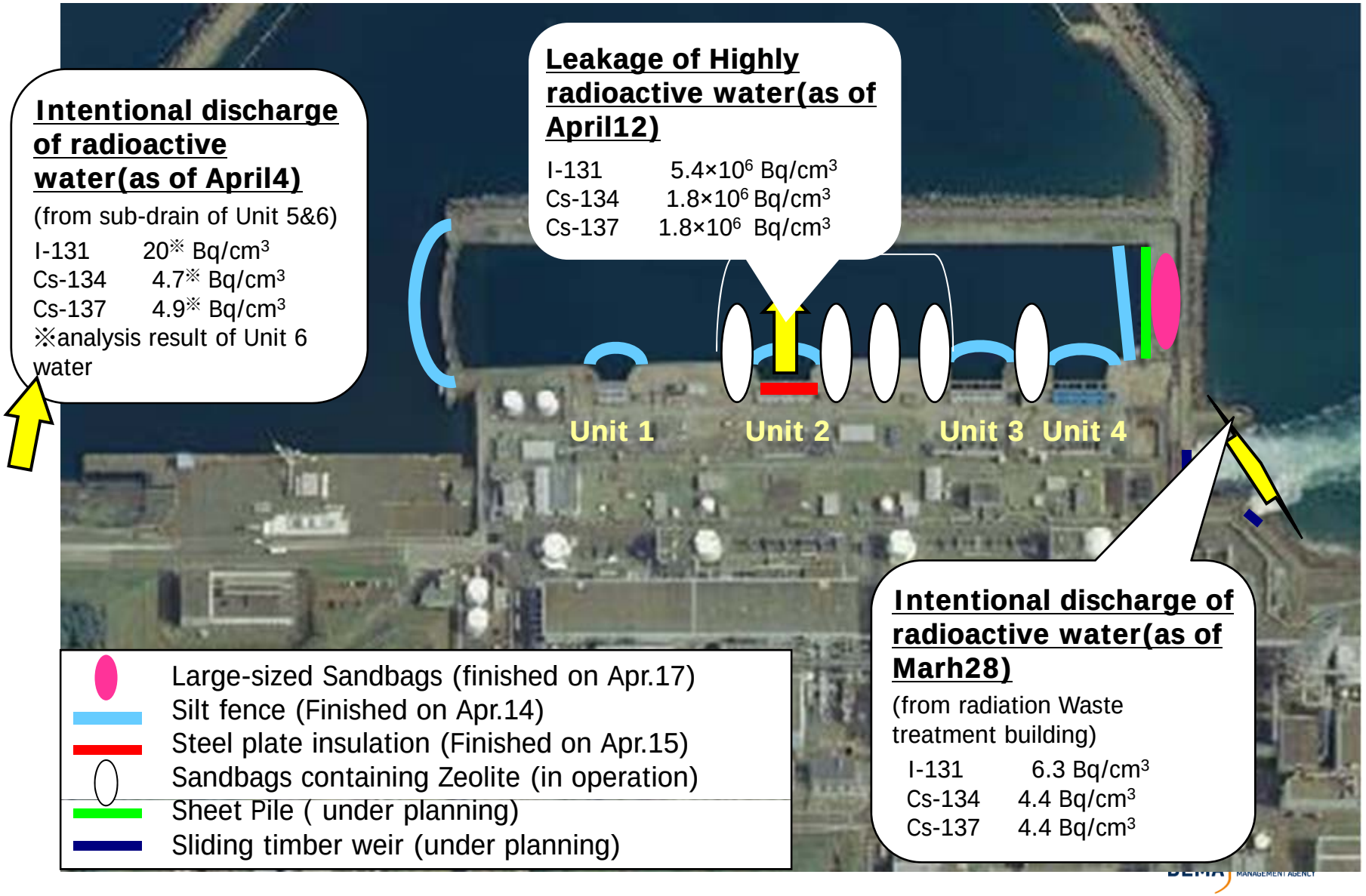
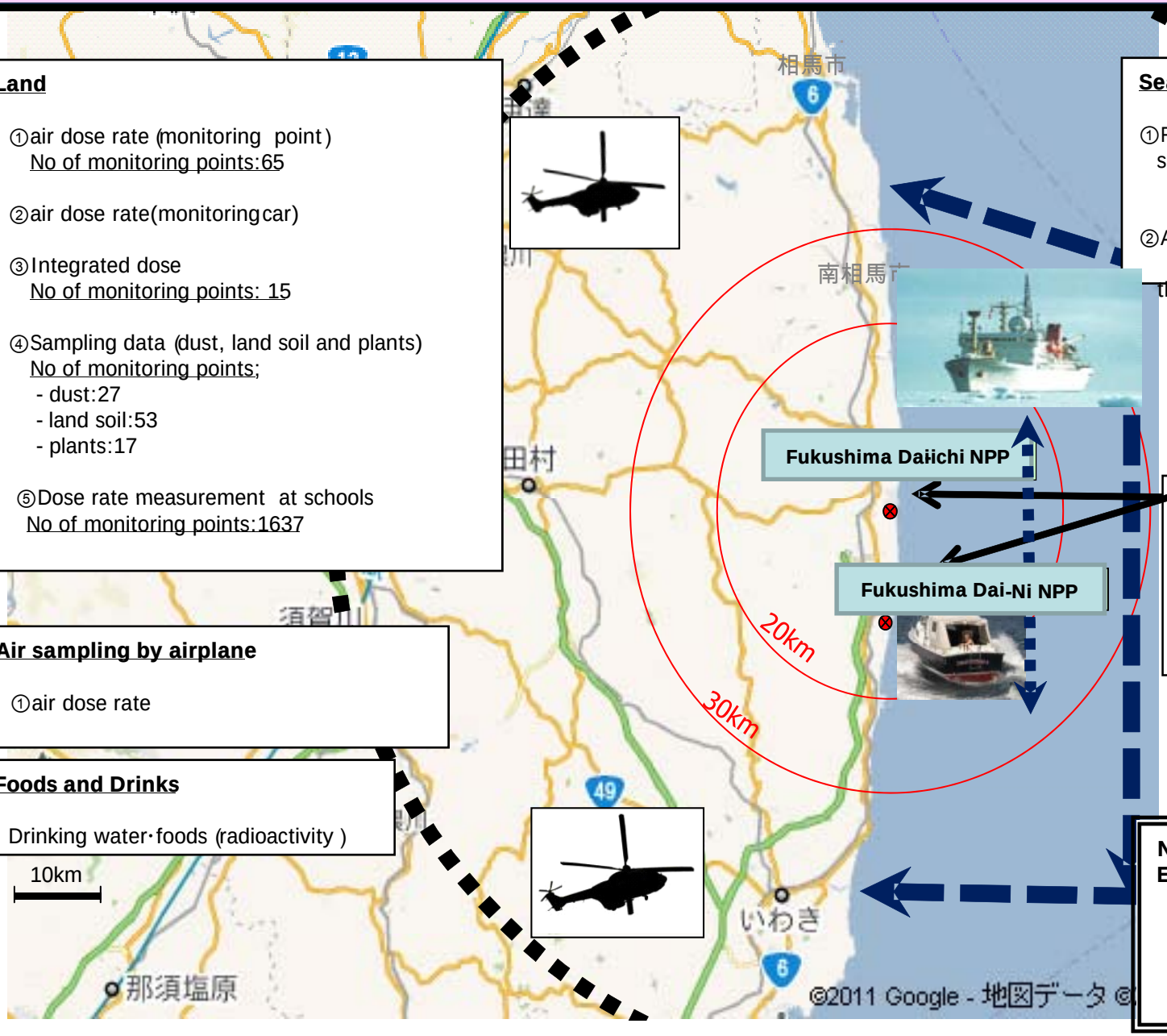
Measures to prevent the spread of radioactive water



- Overview of radiation monitoring around the Fukushima -Daiichi NPP



Land

①air dose rate (monitoring point)
No of monitoring points:65

②air dose rate(monitoring car)

③Integrated dose
No of monitoring points: 15

④Sampling data (dust, land soil and plants)
No of monitoring points;
- dust:27
- land soil:53
- plants:17

⑤Dose rate measurement at schools
No of monitoring points:1637

Air sampling by airplane

①air dose rate

Foods and Drinks

Drinking water･foods (radioactivity)

Sea

①Radioactivity concentration under sea･Air dose rate over the sea (10-30km off the shore)

②Around discharge point and 15km off the shore

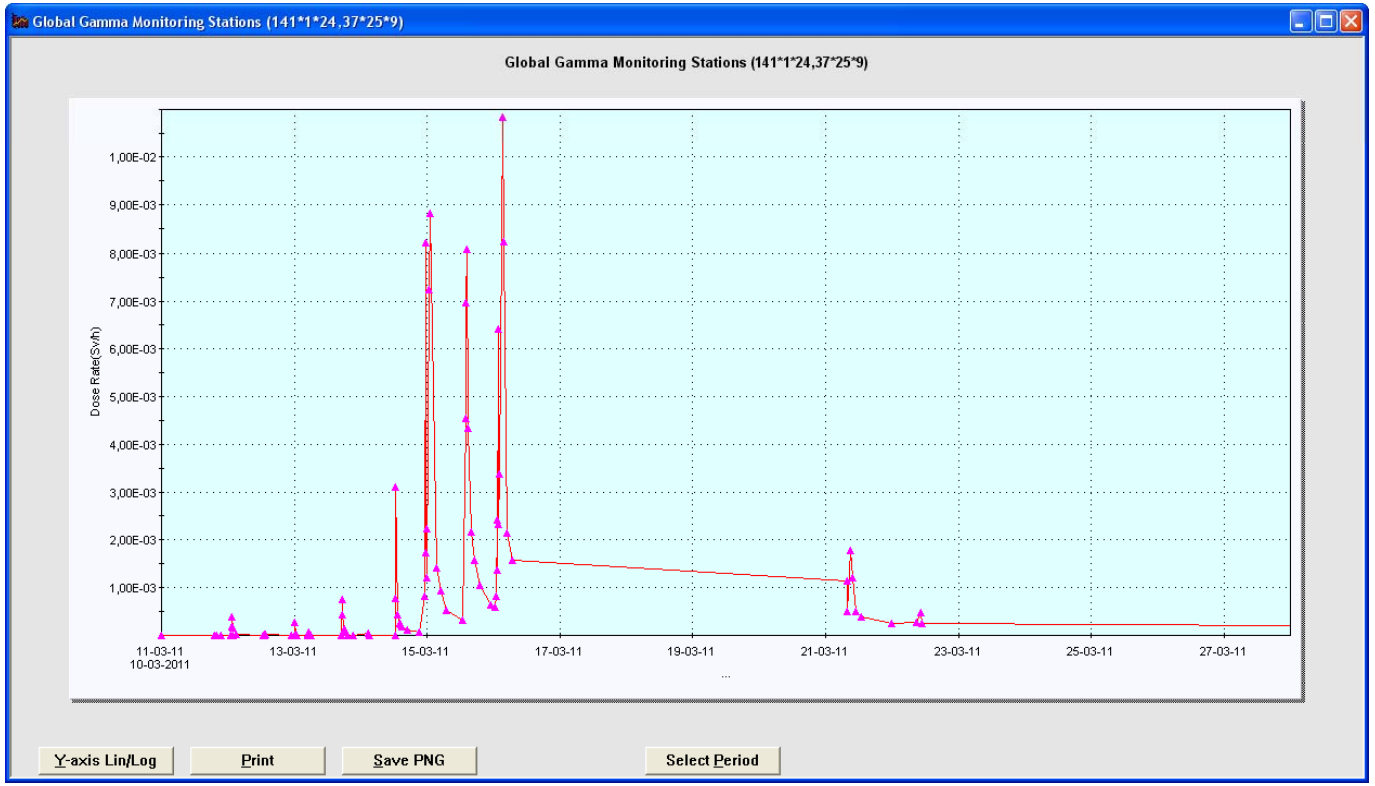
On site

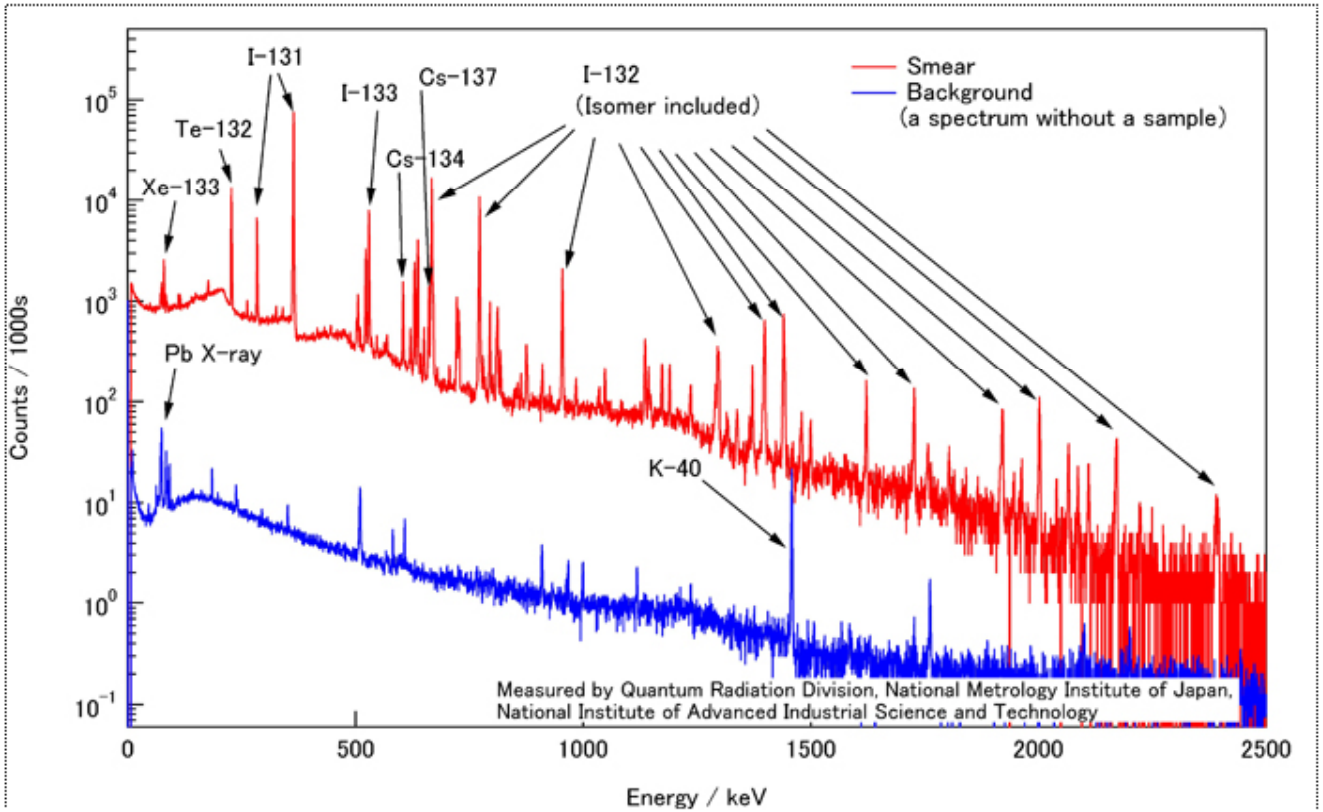
①air dose rate and dust sampling

②radioactivity in land soil

Note:
Each prefecture have been correcting the following paramater
-Air dose rate
- Air borne monitoring
- Drinking water

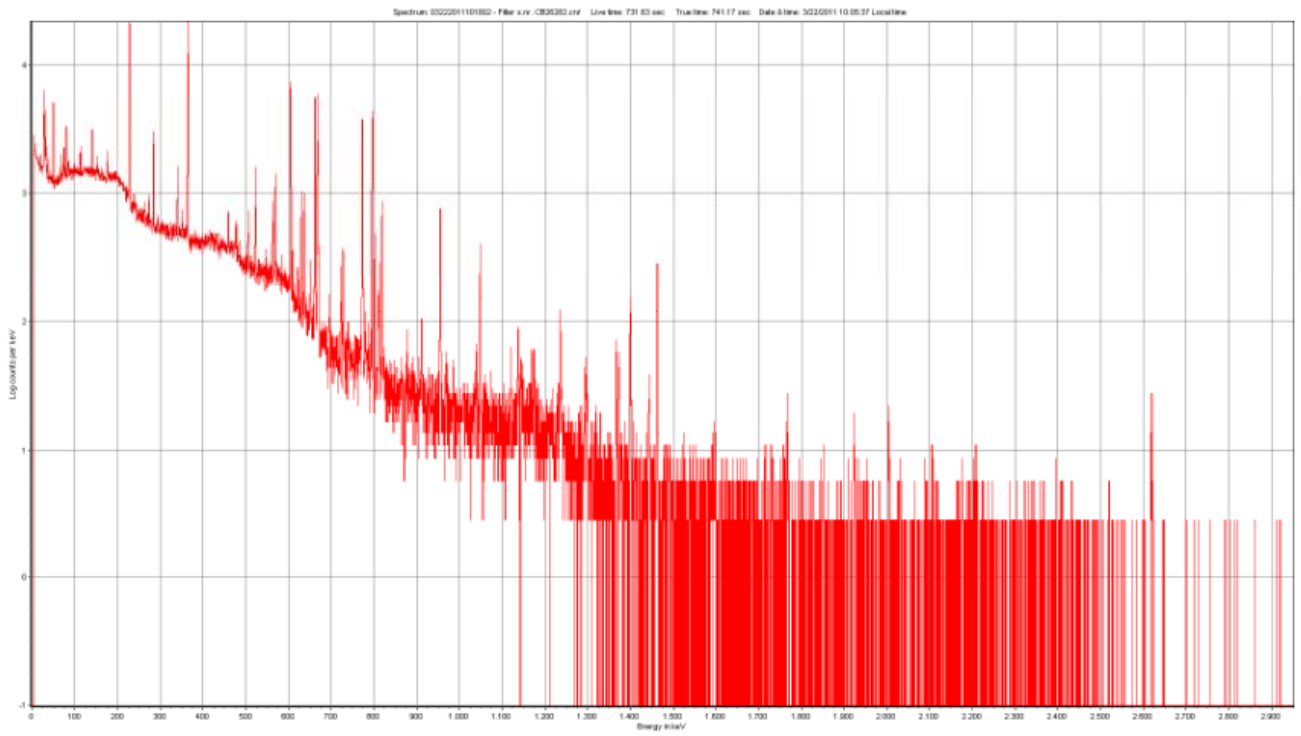
Dose estimates, restrictions etc. in Japan





Photon energy spectra from the fallout sample smeared on the vinyl sheet on the ground (red) at 9:30 March 15, 2011, and the background (blue).

Filter from Air intake in Airbus 240



Evacuation, Sheltering, Stable Iodine

- March11, 21:23 hrs: Government directed **evacuation** of residents **within 3 km radius** of Fukushima Dai-ichi

- March 12, 05:44 hrs: Government directed **evacuation** of residents **within 10 km radius** of Fukushima Dai-ichi

- March 12, 18:25 hrs: Government directed **evacuation** of residents **within 20 km radius** from Fukushima Dai-ichi

- March 15: Local Emergency Response Headquarter issued direction to **administer stable Iodine** during evacuation from the 20 km radius evacuation area

- **Sheltering** of residents was inplemented in the area from 20km to 30km of Fukushima Dai-ichi; and, cooperating with Fukushima Prefecture, livelihood support to the residents in the sheltering area are implemented.

- March 25: Chief Cabinet Secretary announced **voluntary evacuation** of residents within the area from 20 km to 30 km of Fukushima Dai-ichi

DEMA DANISH EMERGENCY MANAGEMENT AGENCY

Radiation exposure to residents and workers

•Fukushima Prefecture has started the screening from 13th March.

•It is carried out at the evacuation sites and the 11 places (set up permanently) such as health offices.

•Up until 11th May, the screening was done to 185,633 people.

•Among them, 102 people were above the 100,000 cpm , but when measured these people again without clothes, etc., the counts decreased to 100,000 cpm and below, and there was no case which affects health. (all the people who were above the value of counting rates were confirmed during 13th – 31st March.)

Worker Dose

Regulation on the dose limit for emergency workers was changed from 100 mSv to 250 mSv on Mar. 14th

• For the 2011 great east Japan earthquake, effective dose limit for emergency workers is 250 mSv, inside the emergency response measures implementation area during the period from the date of the declaration of a nuclear emergency situation to the date of the declaration of the cancellation of the situation.

• To date a total of 30 people have registered exposure dose above 100mSv. Below is some case of exposure to workers: <Laying cables operation>

• On March24, dosage above approx.170mSv was confirmed on 3 workers who were laying cables on 1st floor and basement of Unit3 Turbine Bldg. Attachment of radioactive substances on the skin of both legs was confirmed on two of them.
Examination showed that none of the 3 had any major systemic risk. Exposure dose on the legs of the 2 was estimated to be 2～3Sv.
While the level of leg and internal exposure did not require treatment, they were hospitalized. They were discharged on March 28.

Radioaktivt stoff	*Japan*	*EU*	*Norge*	
Radioaktivt jod				
Drikkevann	300 Bq/kg	500 Bq/kg		
Melk og melkeprodukter	300 Bq/kg	500 Bq/kg		
Barnemat	100 Bq/kg	150 Bq/kg		
Grønnsaker *unntatt rotgrønnsaker*	2000 Bq/kg			
Basismatvarer		2000 Bq/kg		
”Minor foodstuffs”*		20000 Bq/kg		
Radioaktivt cesium				
Drikkevann	200 Bq/kg	1000 Bq/kg		
Melk og melkeprodukter	200 Bq/kg	1000 Bq/kg	370 Bq/kg	
Barnemat		400 Bq/kg	370 Bq/kg	
Grønnsaker	500 Bq/kg			
Korn	500 Bq/kg			
Kjøtt, egg, fisk osv.	500 Bq/kg			
Basismatvarer		1250 Bq/kg	600 Bq/kg	
”Minor foodstuffs” *EU har egen liste på hva disse er; i Norge er det vilt, vill ferskvannsfisk og reinsdyr*		12500 Bq/kg	3000 Bq/kg	
Alfa-emittere, plutonium og transuraner				
Drikkevann	1 Bq/kg	20 Bq/kg		
Melk og melkeprodukter	1 Bq/kg	20 Bq/kg		
Barnemat	1 Bq/kg	1 Bq/kg		
Grønnsaker	10 Bq/kg			
Korn	10 Bq/kg			
Kjøtt, egg, fisk osv.	10 Bq/kg			
Basismatvarer		80 Bq/kg		
”Minor foodstuffs”		800 Bq/kg		
Uran	***Japan***	***EU***	***Norge***	
Drikkevann	20 Bq/kg	1000 Bq/kg§		
Melk og melkeprodukter	20 Bq/kg	1000 Bq/kg		
Barnemat	20 Bq/kg	400 Bq/kg		
Grønnsaker	100 Bq/kg			
Korn	100 Bq/kg			
Kjøtt, egg, fisk osv.	100 Bq/kg			
Basismatvarer		1250 Bq/kg		
”Minor foodstuffs”		12500 Bq/kg		
Radioaktivt strontium				
Drikkevann		125 Bq/kg		
Melk og melkeprodukter		125 Bq/kg		
Barnemat		75 Bq/kg		
Basismatvarer		750 Bq/kg		
”Minor foodstuffs”		7500 Bq/kg		

On site

March 27, 2011

The result of nuclide analysis in the stagnant water on the basement floor of the turbine building of each Unit of Fukushima Dai-ichi Nuclear Power Station

Nuclide (half- life time)	Concentration of Radioactivity (Bq/cm^3)			
	Unit 1 (2nd time) Sampled on March 26	Unit 2 Sampled on March 26	Unit 3 (2nd time) Sampled on March 26	Unit 4 Sampled on March 24
	Dose rate on the surface of the water 60 mSv/h	Dose rate on the surface of the water >1,000 mSv/h	Dose rate on the surface of the water 750 mSv/h	Dose rate on the surface of the water 0.50 mSv/h
Co-56 (about 77 days)	N.D	1.6×10^{5}	N.D	N.D
Co-58 (about 71 days)	N.D	N.D	N.D	2.7×10^{-1}
Co-60 (about 5 years)	N.D	N.D	2.7×10^{2}	N.D
Mo-99 (about 66 hours)	N.D	N.D	N.D	1.0×10^{0}
Tc-99m (about 6 hours)	N.D	8.7×10^{4}	2.2×10^{3}	6.5×10^{-1}
Ru-106 (about 370 days)	N.D	N.D	N.D	3.3×10^{0}
Ag-108m (about 418 years)	N.D	2.5×10^{5}	N.D	N.D
Te-129 (about 70 minutes)	N.D	N.D	N.D	2.6×10^{1}
Te-129m (about 34 days)	N.D	N.D	N.D	1.3×10^{1}
Te-132 (about 3 days)	N.D	N.D	N.D	1.4×10^{1}
I-131 (about 8 days)	1.5×10^{5}	1.3×10^{7}	3.2×10^{5}	3.6×10^{2}
I-132 (about 2 hours)	N.D	N.D	N.D	1.3×10^{1}
I-134 (about 53 minutes)	N.D	2.9×10^{9}	N.D	N.D
Cs-134 (about 2 years)	1.2×10^{5}	2.3×10^{6}	5.5×10^{4}	3.1×10^{1}
Cs-136 (about 13 days)	1.1×10^{4}	2.5×10^{5}	6.5×10^{3}	3.7×10^{0}
Cs-137 (about 30 years)	1.3×10^{5}	2.3×10^{6}	5.6×10^{4}	3.2×10^{1}
Ba-140 (about 13 days)	N.D	4.9×10^{5}	1.9×10^{4}	N.D
La-140 (about 2 days)	N.D	1.9×10^{5}	3.1×10^{3}	7.4×10^{-1}

N.D : Not Detectable

DEMA DANISH EMERGENCY MANAGEMENT AGENCY

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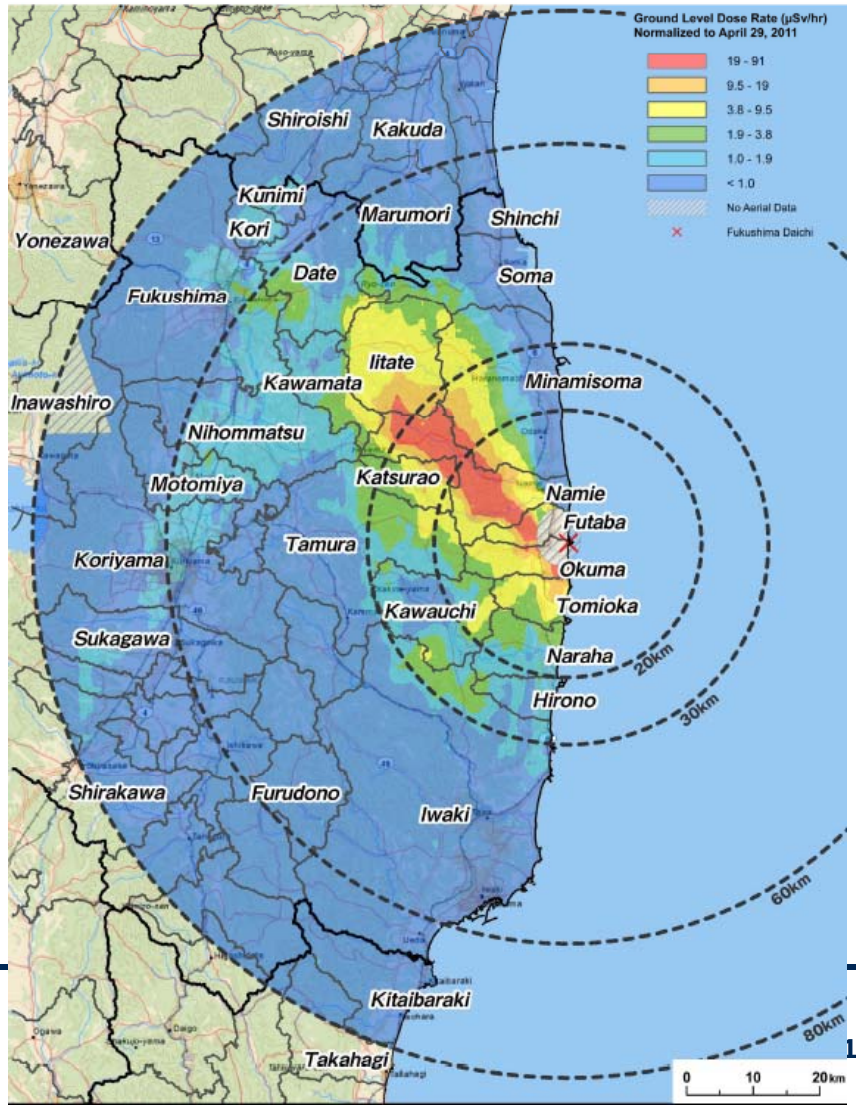
Source Term

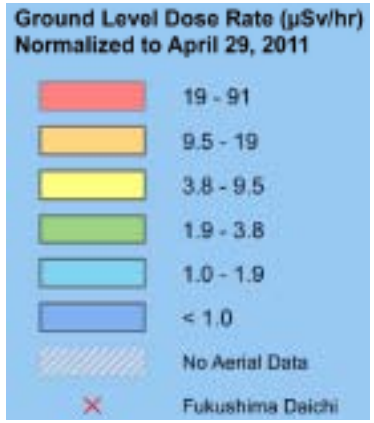
	Assumed amount of the discharge from Fukushima Dai-ichi (1F)		(Reference) Amount of the discharged from the Chernobyl accident
	NISA's estimation *1	NSC's estimation*2	
^{131}I...(a)	$1.3*10^{17}$Bq	$1.5*10^{17}$Bq	$1.8*10^{18}$Bq
^{137}Cs	$6.1*10^{15}$Bq	$1.2*10^{16}$Bq	$8.5*10^{16}$Bq
(Converted value to ^{131}I)*3 ...(b)	$2.4*10^{17}$Bq	$4.8*10^{17}$Bq	$3.4*10^{18}$Bq
(a)+(b)	$3.7*10^{17}$Bq	$6.3*10^{17}$Bq	$5.2*10^{18}$Bq

(notes)
*1: Estimation by NISA is based on the numerical analysis of accident transient
*2: NSC calculated backward of monitoring data to estimate the amount of discharge
*3: multiplication factor of radiological equivalence to ^{131}I is 40

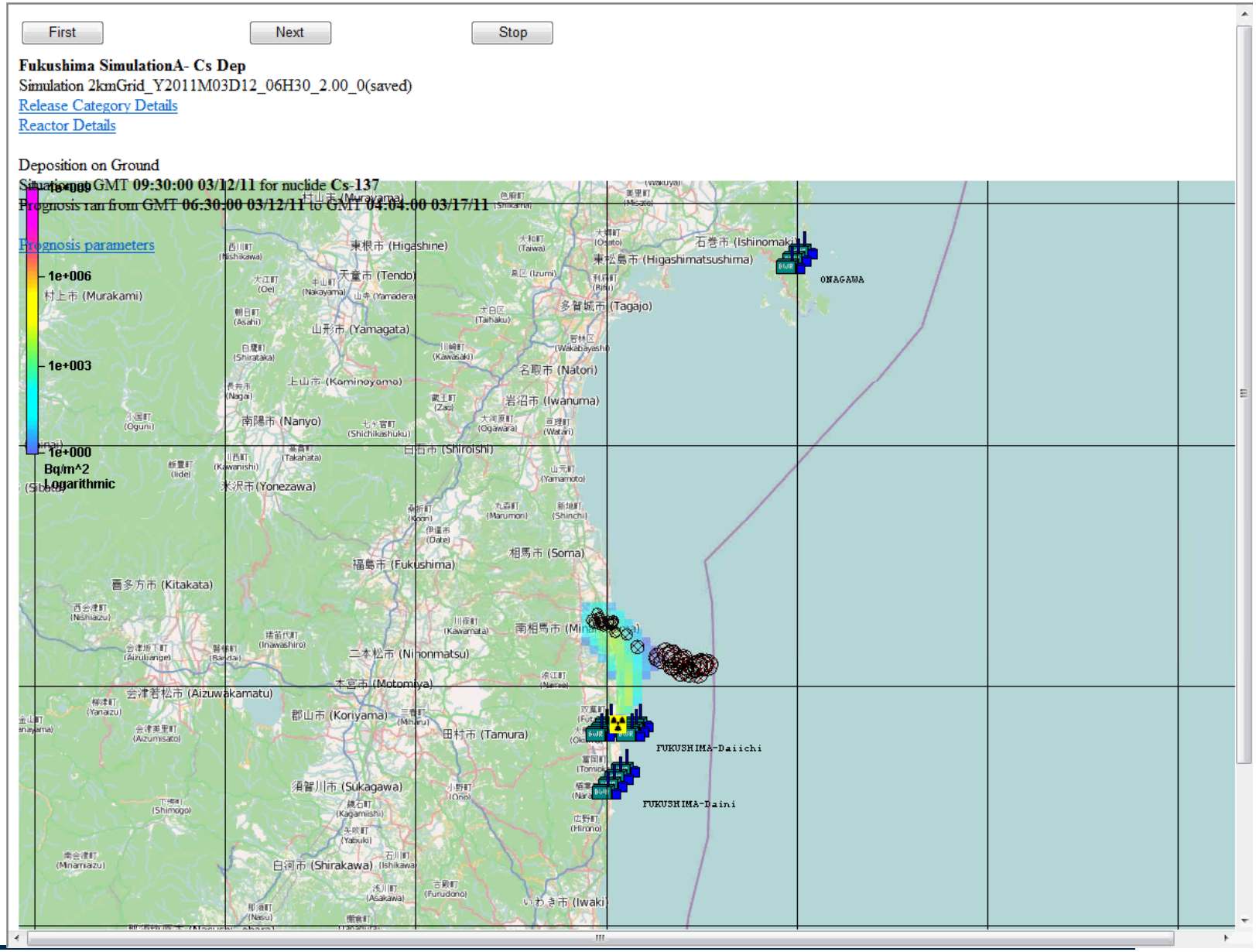
Aerial Measuring Results

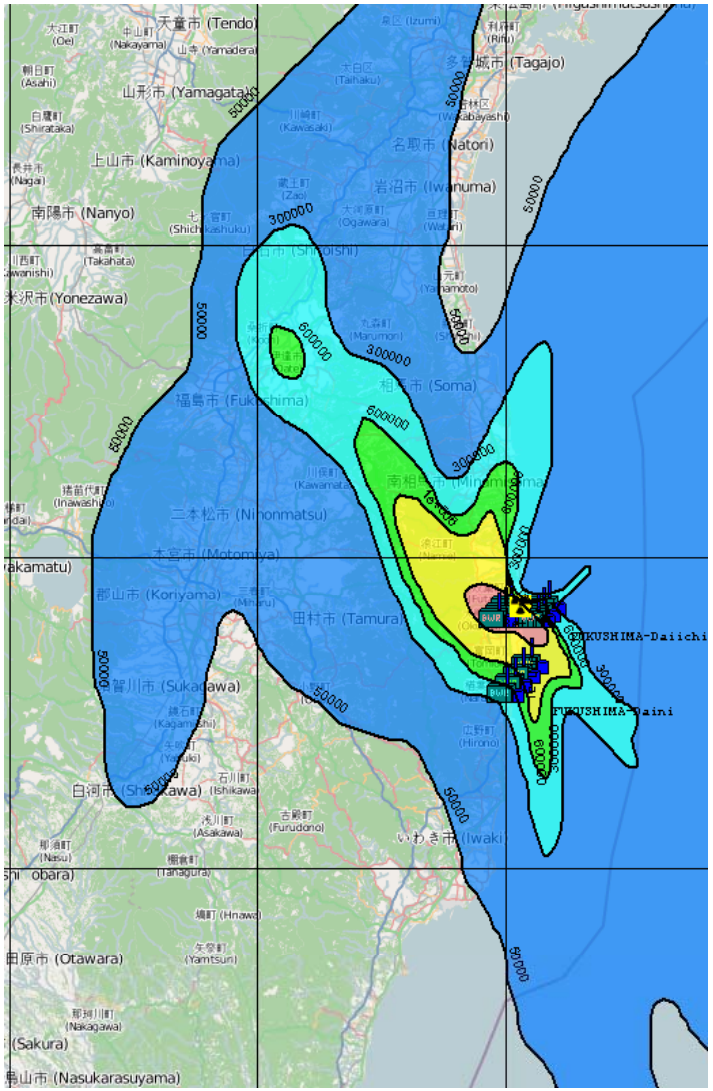
Joint US / Japan Survey Data





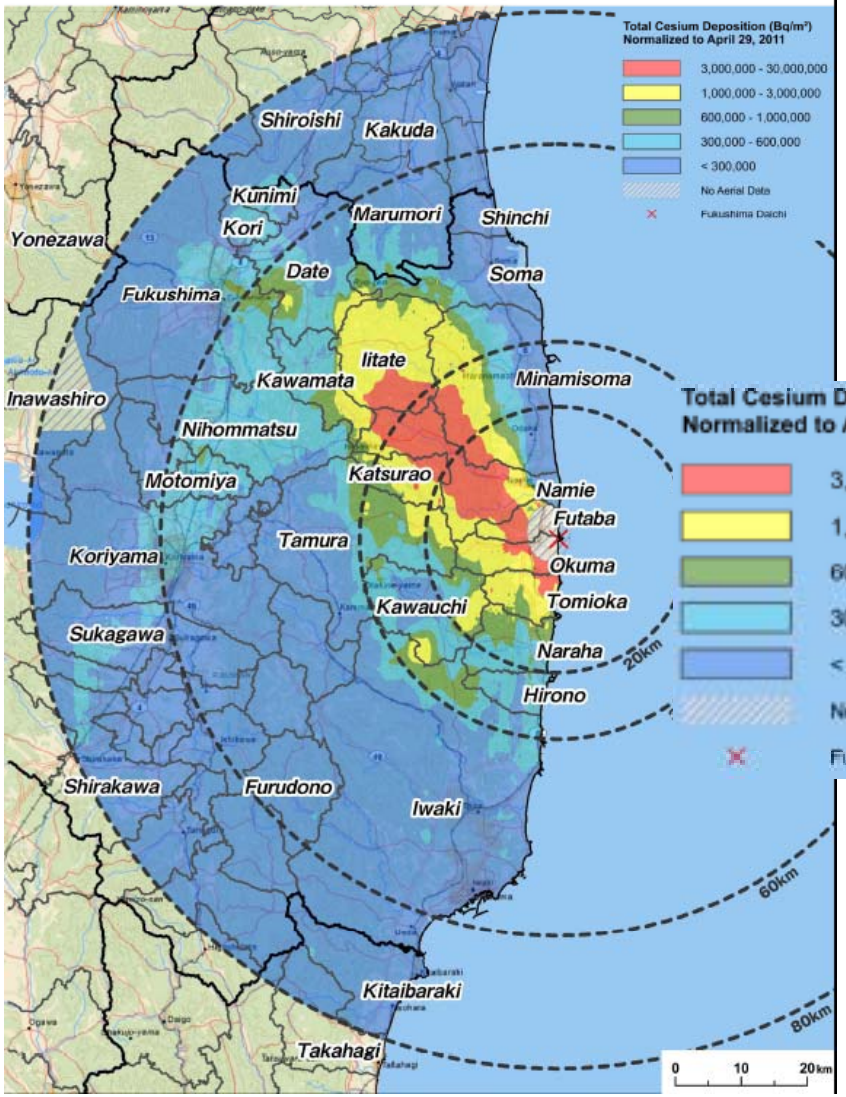
DEMA DANISH EMERGENCY MANAGEMENT AGENCY


First
Next
Stop
Fukushima SimulationA- Cs Dep
Simulation 2kmGrid_Y2011M03D12_06H30_2.00_0(saved)
Release Category Details
Reactor Details
Deposition on Ground
Situation at GMT 09:30:00 03/12/11 for nuclide Cs-137
Prognosis ran from GMT 06:30:00 03/12/11 to GMT 04:04:00 03/17/11
Prognosis parameters
1e+009
1e+006
1e+003
1e+000
Bq/m^2
Logarithmic
東根市 (Higashine)
天童市 (Tendo)
村上市 (Murakami)
山形市 (Yamagata)
上山市 (Kaminoyama)
南陽市 (Nanyo)
米沢市 (Yonezawa)
白石市 (Shiroishi)
名取市 (Natori)
岩沼市 (Iwanuma)
多賀城市 (Tagajo)
東松島市 (Higashimatsushima)
石巻市 (Ishinomaki)
ONAGAWA
相馬市 (Soma)
福島市 (Fukushima)
喜多方市 (Kitakata)
二本松市 (Nihonmatsu)
本宮市 (Motomiya)
会津若松市 (Aizuwakamatu)
郡山市 (Koriyama)
田村市 (Tamura)
須賀川市 (Sukagawa)
白河市 (Shirakawa)
いわき市 (Iwaki)
FUKUSHIMA-Daiichi
FUKUSHIMA-Daini

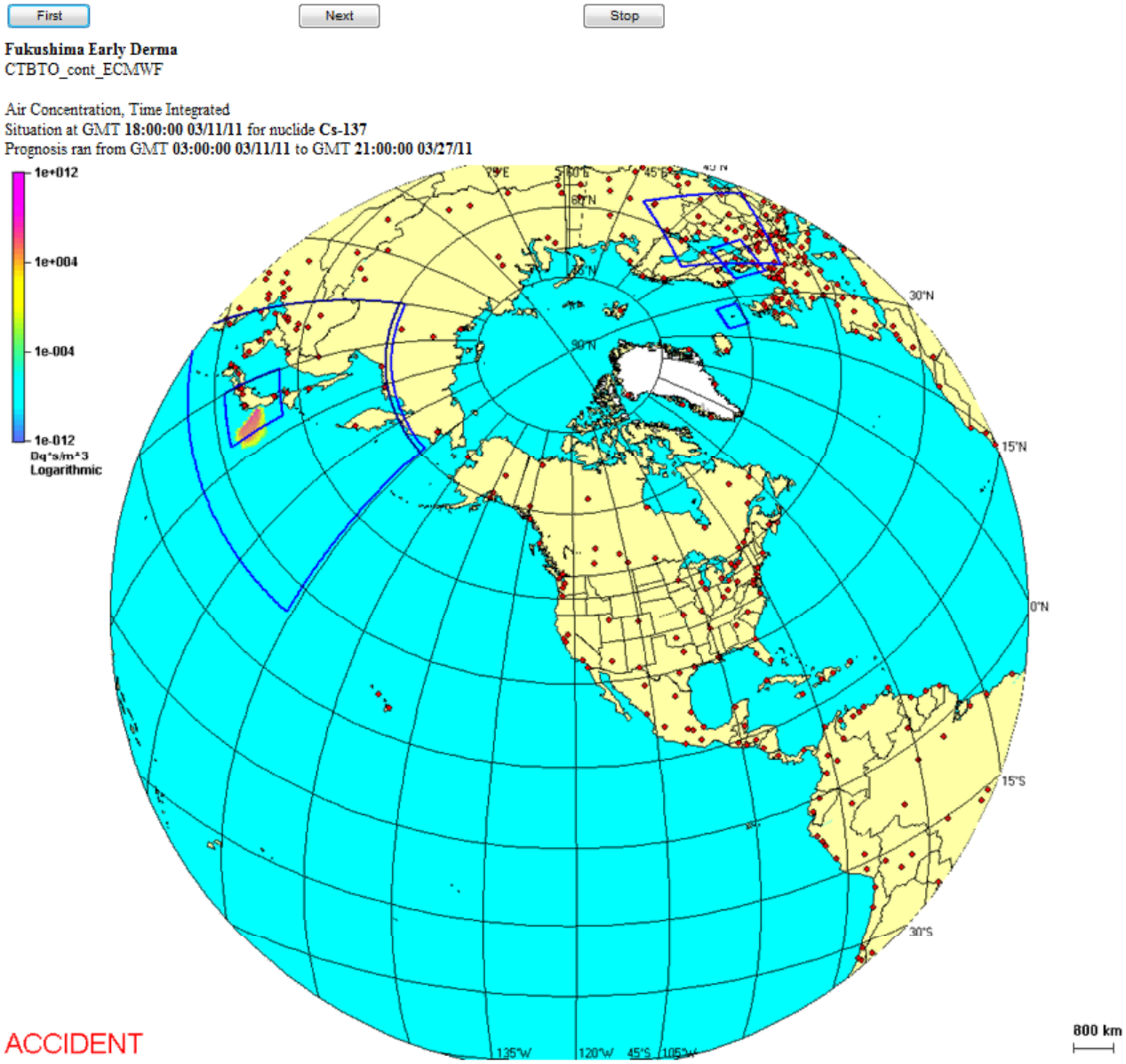


Aerial Measuring Results

Joint US / Japan Survey Data



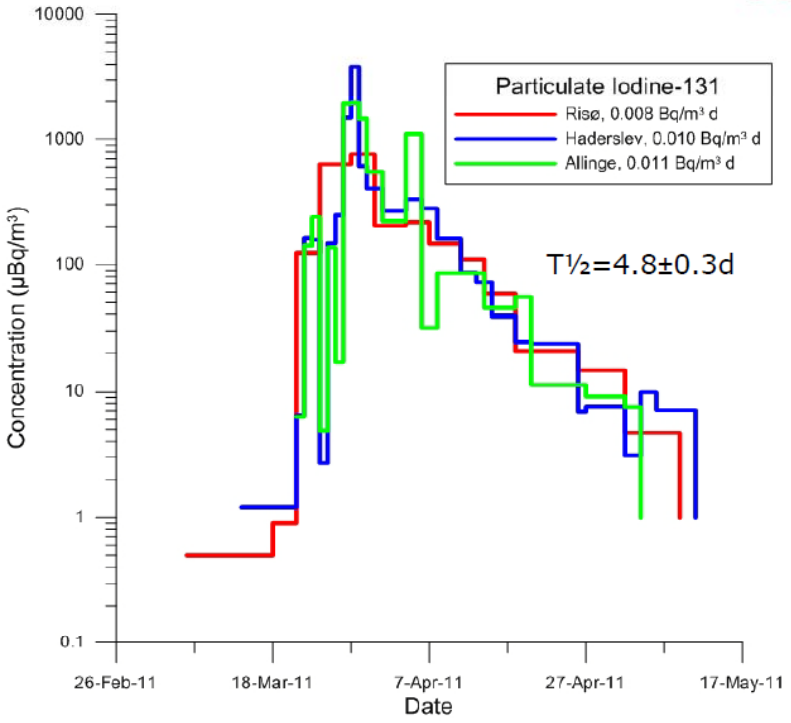
DEMA DANISH EMERGENCY MANAGEMENT AGENCY


First
Next
Stop
Fukushima Early Derma
CTBTO_cont_ECMWF
Air Concentration, Time Integrated
Situation at GMT 18:00:00 03/11/11 for nuclide Cs-137
Prognosis ran from GMT 03:00:00 03/11/11 to GMT 21:00:00 03/27/11
1e+012
1e+004
1e-004
1e-012
Bq*s/m^3
Logarithmic
30°N
15°N
0°N
15°S
30°S
135°W
120°W
45°S
800 km
ACCIDENT

Risø/BRS målestationer

Iodine-131 in Air in Denmark

- Samples based on collection of particles in air by filtration
- Thus gaseous fraction of iodine not collected
- Other labs in Europe using filters and charcoal cartridges for air sampling found two to ten times more gaseous than particulate iodine
- Time-integrated concentrations of ^{131}I in air at three Danish locations range from 0.008 to 0.011 Bq/m³ d.



5 Risø DTU, Technical University of Denmark NUK Seminar 16 May 2011